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LRTP MATHEMATICAL MODEL BROCHURE

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Prepared for:

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Buffalo 21, N.Y.

LRTP MATHEMATICAL MODEL BROCHURE

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REPORT NO. VQ-2044-H-3
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1. INTRODUCTION

This brochure contains a technical description of the LRTP Choice Model derived in Cornell Aeronautical Report No. VQ-2044-H-2, "The LRTP Process as it Relates to the U.S. Army Materiel Command". The brochure is self-contained in that the technical aspects may be read and understood without referring to the above report.

This brochure is divided into three sections, excluding the Introduction. Section 2 gives a mathematical description of the model. Section 3 contains a description of the computer program which includes flow charts, a FORTRAN listing and a debugging log. Section 4 contains several numerical examples of program outputs using hypothetical input data.

2. MATHEMATICAL DESCRIPTION OF THE LRTP CHOICE MODEL

This section presents a mathematical description of the LRTP Choice Model to the extent necessary for programming the model.

The description is given in four parts. Section 2.1 provides a description of the relationships between the conceptual elements generated by the LRTP planning process. Section 2.2 gives a mathematical description of the model and Section 2.3 gives the procedure used to approximate solutions. Section 2.4 contains a summary of symbols.

2.1 Structural Relationships

The choice problem begins with a given set of Major Barrier Problem Areas (MBPA's) where each MBPA has been derived from one or more Research Development Objectives (RDO's). Accompanying each MBPA is a binary statement as to whether or not a minimum research and

development work effort must be funded. Also, each MBPA has three numerical values associated with it. The first is the estimated expected probability that an RDO will appear at some future date in the form of a Qualitative Materiel Development Objective (QMDO) or a Qualitative Materiel Requirement (QMR). The second is the estimated expected probability that the MBPA will be encountered in a Technical Approach given that an RDO containing the MBPA appears in the form of a QMDO or QMR. The third value associated with each MBPA is its estimated essentiality relative to other MBPA's. The essentiality is assumed to be derived from priorities assigned to RDO's.

In order to overcome the MBPA's, one or more alternative Tasks (TK's) are proposed for each MBPA; any Task proposed for an MBPA will overcome it if successful. A Task is defined in terms of a sequence of annual Work Efforts (WE's), and associated with each annual Work Effort is an estimated conditional probability of success, estimated cost and a Monetary Quota to which it is assigned. A Monetary Quota represents a Field Establishment assigned to conduct the work. A Task is said to be successful if all of the annual Work Efforts associated with the Task are successful.

The above relationships are indicated in Figure 2-1.

The problem is to determine possible combinations of Tasks for funding (and consequently those not to fund) that maximize the expected Technical Value of the LRTP program and satisfy given minimum costs assigned the Monetary Quotas and MBPA minimum Work Effort statements.

Henceforth, a combination of Tasks will be called a Configuration.

MAJOR BARRIER PROBLEM AREAS

1. Binary statement concerning minimum funding
2. Probability of appearance in RDO
3. Probability that it will be encountered
4. Essentiality

PROPOSED ALTERNATIVE TASKS

PROBLEM: Determine combinations of Tasks for possible funding subject to constraints

SEQUENCES OF ANNUAL WORK EFFORTS

1. Probability of success
2. Cost
3. Monetary Quota

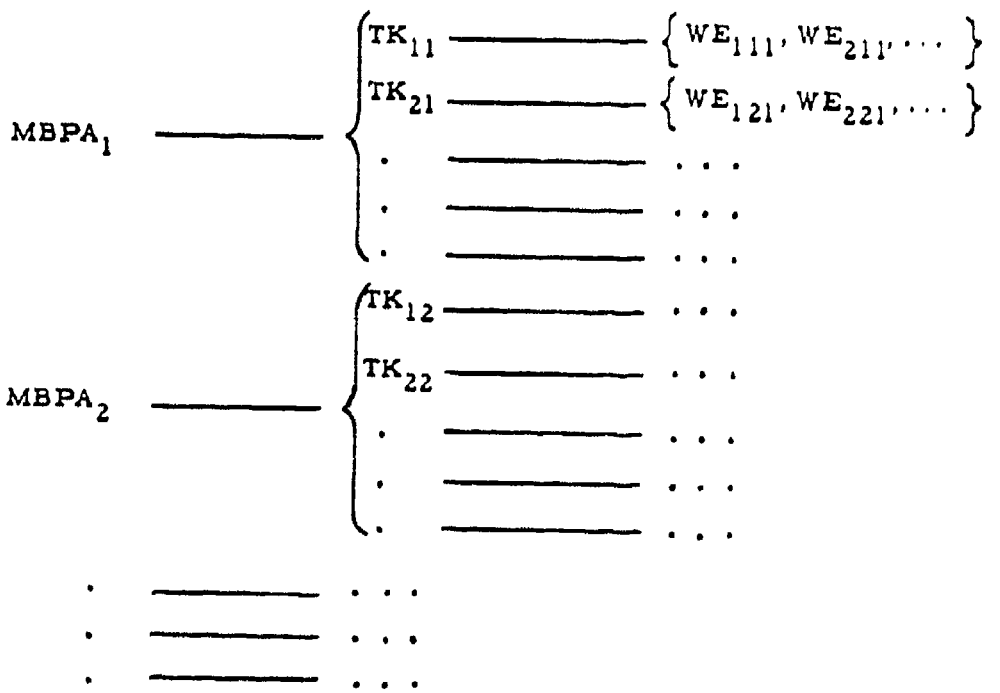


Figure 2-1. Structural Relationships

2.2 Mathematical Description

2.2.1 Problem Formation

Let R denote the Configuration set where R is of the form:

$$R(r) = \prod_{k=1}^{a} R_k (r_k) \quad \text{(direct product set)}$$

where a Configuration $r \in R$ consists of an ordered a-tuple $(r_1, r_2, \ldots, r_k, \ldots, r_a)$ of Configurations, one for each MBPA. Defined on the Configuration set is a function V(r) called the expected Technical Value of a Configuration. Also defined on the Configuration set are three cost functions. The first cost function C(r) is called the Annual Cost of a Configuration and is expressed as a single value. The second cost function Q(r) is called the Annual Monetary Quota Cost of a Configuration and is expressed as an ordered b-tuple $(q_1, q_2, \ldots, q_n, \ldots, q_b)$ of annual costs, one for each Monetary Quota. The third cost function E(r) is called the Expected Cost of a Configuration and is expressed as a single value.

The expected Technical Value and Costs of an LRTP Configuration are given by:

$$(1) \quad V(r) = \sum_{k=1}^{a} V_k(r_k)$$

$$(2) \quad C(r) = \sum_{k=1}^{a} C_k(r_k)$$

$$(3) \quad Q(r) = \sum_{k=1}^{a} Q_k(r_k)$$

$$(4) \quad E(r) = \sum_{k=1}^{a} E_k(r_k)$$

where

$V_k(r_k)$ = the expected Technical Value of a Configuration for the k-MBPA

$C_k(r_k)$ = the Annual Cost of a Configuration for the k-th MBPA

$Q_k(r_k)$ = the Annual Monetary Quota Cost of a Configuration for the k-th MBPA

$E(r_k)$ = the Expected Cost of a Configuration for the k-th MBPA.

Given the above relationships and a Monetary Quota constraint F, where F is an ordered b-tuple $(f_1, f_2, \ldots, f_n, \ldots, f_b)$ of minimum funds, one for each Monetary Quota and binary statements h_k, one for each MBPA, the problem is to determine

$$\max \left\{ V(r) \mid r \in R \right\}$$

subject to

$$Q(r) \geq F \quad (q_n \geq f_n \text{ for all } n)$$

and the conditions imposed by the binary statements.

2.2.2 The MBPA Configuration Set

A Configuration for the k-th MBPA $r_k \in R_k$ consists of an ordered d_k-tuple of the form $(r_{1k}, r_{2k}, \ldots, r_{jk}, \ldots, r_{d_k k})$ where r_{jk} can take on one of two values, say either 1 or 0;

$r_{jk} = 1$ denotes the j-th Task proposed for the k-th MBPA is represented in the r_k Configuration

$r_{jk} = 0$ denotes the j-th Task proposed for the k-th MBPA is not represented in the r_k Configuration.

Let

h_k = a binary statement as to whether or not a minimum research and development work effort for the k-th MBPA must be funded

where

$h_k = 1$ denotes the k-th MBPA must be funded

$h_k = 0$ denotes the k-th MBPA does not necessarily have to be funded.

Given $h_k = 1$, the Configuration set R_k for the k-th MBPA consists of all Configurations r_k that have at least one Task represented in them. Given $h_k = 0$, the Configuration set R_k for the k-th MBPA consists of all possible combinations where there are 2^{d_k} combinations (Configurations) represented in the set.

2.2.3 The Expected Technical Value of an MBPA Configuration

Let

p_{ijk} = estimated conditional probability of success of the i-th WE of the j-th Task proposed for the k-th MBPA, $i=1, 2, \ldots, m_{jk}$

U_k = expected probability that an RDO will appear at some future date and contain the k-th MBPA

w_k = estimated expected probability that the k-th MBPA will be encountered in a Technical Approach given that an RDO containing the MBPA appears at some future date

u_k = number of RDO's that the k-th MBPA is associated with

s = total number of RDO's.

Then, the estimated probability U_k is given by

$$(5)\quad U_k = u_k/s.$$

The probability of success $P_{jk}(r_{jk})$ of the j-th Task proposed for the k-th MBPA is given by

$$(6)\quad P_{jk}(r_{jk} = 1) = \prod_{i=1}^{m_{jk}} p_{ijk}$$

$$(7)\quad P_{jk}(r_{jk} = 0) = 0.$$

The probability that the j-th Task proposed for the k-th MBPA fails $N_{jk}(r_{jk})$ is given by

$$(8)\quad N_{jk}(r_{jk}) = 1 - P_{jk}(r_{jk})$$

The probability that at least one Task is successful $S_k(r_k)$ in overcoming the k-th MBPA is given by

$$(9)\quad S_k(r_k) = 1 - \prod_{j=1}^{d_k} N_{jk}(r_{jk}).$$

Finally, the expected Technical Value of a Configuration for the k-th MBPA is given by

$$(10)\quad V_k(r_k) = U_k w_k e_k S_k(r_k).$$

2.2.4 The Annual Cost of a Configuration for an MBPA

Let

c_{ijkn} = estimated cost of the i-th annual Work Effort of the j-th Task proposed for the k-th MBPA and assigned to the n-th Monetary Quota.

The annual cost of the j-th Task $C_{jk}(r_{jk})$ proposed for the k-th MBPA is given by

$$(11)\quad C_{jk}(r_{jk} = 1) = c_{1\ jkn'}$$

$$(12)\quad C_{jk}(r_{jk} = 0) = 0$$

and the Annual Cost $C_k(r_k)$ of a Configuration for the k-th MBPA is given by

$$(13)\quad C_k(r_k) = \sum_{j=1}^{d_k} C_{jk}(r_{jk})$$

2.2.5 The Annual Monetary Quota Cost of a Configuration for an MBPA

The annual Monetary Quota Cost $Q_{jk}(r_{jk})$ of the j-th Task proposed for the k-th MBPA is given by

$$(14)\quad Q_{jk}(r_{jk}=1) = (y_1, y_2, \ldots, y_n, \ldots, y_b)$$

where

$$y_n = \delta\, c_{1\ jkn'}$$

$$\delta = \begin{cases} 1 \text{ for } n = n' \\ 0 \text{ otherwise} \end{cases}$$

and

$$(15)\quad Q_{jk}(r_{jk} = 0) = 0 \ (y_n = 0 \text{ for all } n)$$

The Monetary Quota Cost $Q_k(r_k)$ of a Configuration for the k-th MBPA is given by

$$(16)\quad Q_k(r_k) = \sum_{j=1}^{d_k} Q_{jk}(r_{jk})$$

2.2.6 The Expected Cost of a Configuration for an MBPA

The expected cost $E_{jk}(r_{jk})$ of the j-th Task associated with the k-th MBPA is given by

$$(17)\quad E_{jk}(r_{jk} = 1) = c_{1\ jkn} + \sum_{i=2}^{m_{jk}} p_{ijk}\, c_{ijkn}$$

$$(18)\quad E_{jk}(r_{jk} = 0) = 0.$$

The expected cost $E_k(r_k)$ of a Configuration for the k-th MBPA is given

$$(19)\quad E_k(r_k) = \sum_{j=1}^{d_k} E_{jk}(r_{jk}).$$

2.3 Method of Approximation

The purpose of this section is to list the steps employed in determining

$$\max \left\{ V(r) \;\middle|\; r \in R \right\}$$

subject to

$$Q(r) \geq F$$

and the MBPA binary work effort statements.

The methodolcgy presented herein is similar to that described in Cornell Aeronautical Laboratory Report No. VQ-1887-H-1, May 19, 1964. As indicated in the report, the method is one of approximation and the results are not necessarily true maximums.

2.3.1 Description

The steps employed to approximate the set of Configurations with maximum Expected Technical Value subject to Monetary Quota Costs and MBPA binary work effort statements may briefly be described as follows:

1. Set $r_k = 1$. $r_k = 1$ denotes an MBPA Configuration consisting of all Tasks proposed for the MBPA.)

2. Compute $V_k(r_k)$, $E_k(r_k)$.

3. For each Task compute

$$\frac{\Delta V_{jk}}{\Delta E_{jk}} = \frac{V_k(r_k) - V_k(r_k^j)}{E_k(r_k) - E(r_k^j)}$$

where r_k^j denotes the r_k Configuration without the j-th Task of the k-th MBPA.

4. Rank the Tasks in order of increasing $\Delta V_{jk}/\Delta E_{jk}$, $j_1, j_2, \ldots, j_{x+1}, \ldots$; x=0, 1, 2...

5. Set r=1 (r=1 denotes the Configuration consisting of all proposed Tasks.)

6. Determine if $Q(r) \geq F$. If the statement is true, proceed to the next step. If the statement is false, stop computation.

7. Set x=0.

8. Determine if $Q(r^{j_{x+1}}) \geq F$ where $r^{j_{x+1}}$ denotes the r-th Configuration with the j_{x+1} Task removed. If the statement is true proceed to the next step; if false, go to step 11.

9. If $h_k = 1$, determine if at least one Task for the k-th MBPA is represented in the Configuration $r^{j_{x+1}}$. If yes, proceed to the next step, if not, go to step 11.

10. Set $r^{j_{x+1}} = r+1$ and $r = r^{j_{x+1}}$.

11. Set $x = x+1$ and go to step 8.

The above procedure is repeated until all Tasks in the rank ordering have been considered.

2.4 Summary of Symbols

2.4.1 Subscripts

k= identification number of a Major Barrier Problem Area. $k = 1, 2, \ldots, a$.

j= identification number of a Task. $j = 1, 2, \ldots, d_k$.

i= identification number of an Annual Work Effort. $i = 1, 2, \ldots, m_{jk}$.

n= identification number of a Monetary Quota. $n = 1, 2, \ldots, b$.

2.4.2 Inputs

FOR EACH MAJOR BARRIER PROBLEM AREA (MBPA)

h_k= a binary statement as to whether or not a minimum research and development work effort for the k-th MBPA must be funded

where

$h_k=1$ denotes the k-th MBPA must be funded.

$h_k=0$ denotes the k-th MBPA does not necessarily have to be funded.

u_k= number of Research Development Objectives (RDO's) that the k-th MBPA is associated with.

w_k= estimated expected probability that the k-th MBPA will be encountered in a Technical Approach given that an RDO containing the MBPA appears at some future date.

e_k= the Technical Essentiality assigned to the k-th MBPA.

FOR EACH ANNUAL WORK EFFORT (WE)

p_{ijk}= estimated conditional probability of success of the i-th WE of the j-th Task proposed for the k-th MBPA.

c_{ijkn}= estimated cost of the i-th WE of the j-th Task proposed for the k-th MBPA and assigned to the n-th Monetary Quota

OTHER INPUTS

s= total number of RDO's

F= minimum amount of funds that must be allocated to each Monetary Quota where F is an ordered b-tuple $(f_1, f_2, \ldots, f_n, \ldots, f_b)$ funds, one for each Monetary Quota.

2.4.3 Auxiliary Symbols

$V_k(r_k)$ = expected Technical Value of a Configuration for the k-th MBPA

$C_k(r_k)$ = the Annual Cost of a Configuration for the k-th MBPA

$Q_k(r_k)$ = the Annual Monetary Quota Cost of a Configuration for the k-th MBPA

$E_k(r_k)$ = the Expected Cost of a Configuration for the k-th MBPA

U_k = expected probability that an RDO sill appear at some future date and contain the k-th MBPA

$P_{jk}(r_{jk})$ = probability of success of the j-th Task proposed for the k-th MBPA

$N_{jk}(r_{jk})$ = probability that the j-th Task proposed for the k-th MBPA fails

$S_k(r_k)$ = probability that at least one Task included in the r_k Configuration is successful

C_{jk} = annual cost of the j-th Task proposed for the k-th MBPA

$Q_{jk}(r_{jk})$ = annual Monetary Quota Cost of the j-th Task proposed for the k-th MBPA

$E_{jk}(r_{jk})$ = the expected cost of the j-th Task proposed for the k-th MBPA.

2.4.4 Outputs

r = identification number of a Configuration. r=1, 2, ...

(j, k)= identification of Tasks included in the r-th Configuration

V(r)= the expected Technical Value of the r-th Configuration

C(r)= the Annual Cost of the r-th Configuration

$\Delta V(r)$= the difference between the expected Technical Values of the r-th and r-1 Configurations

$\Delta C(r)$= the difference between the Annual Costs of the V-th and r-1 Configurations

Q(r) = the Annual Monetary Quota Cost of the r-th Configuration.

3. COMPUTER PROGRAM FOR LRTP MODEL

This section contains a description of the computer program which processes data for the LRTP model. The inputs and the outputs of the program are illustrated and the method of organizing information which controls the program's operation is presented.

The computer program has been written in the FORTRAN IV language. It is prepared for operation under the control of IBSYS, the operating system used for several IBM computers (work on this project was conducted at a 7090-1401 computing center).

3.1 Description of the Program

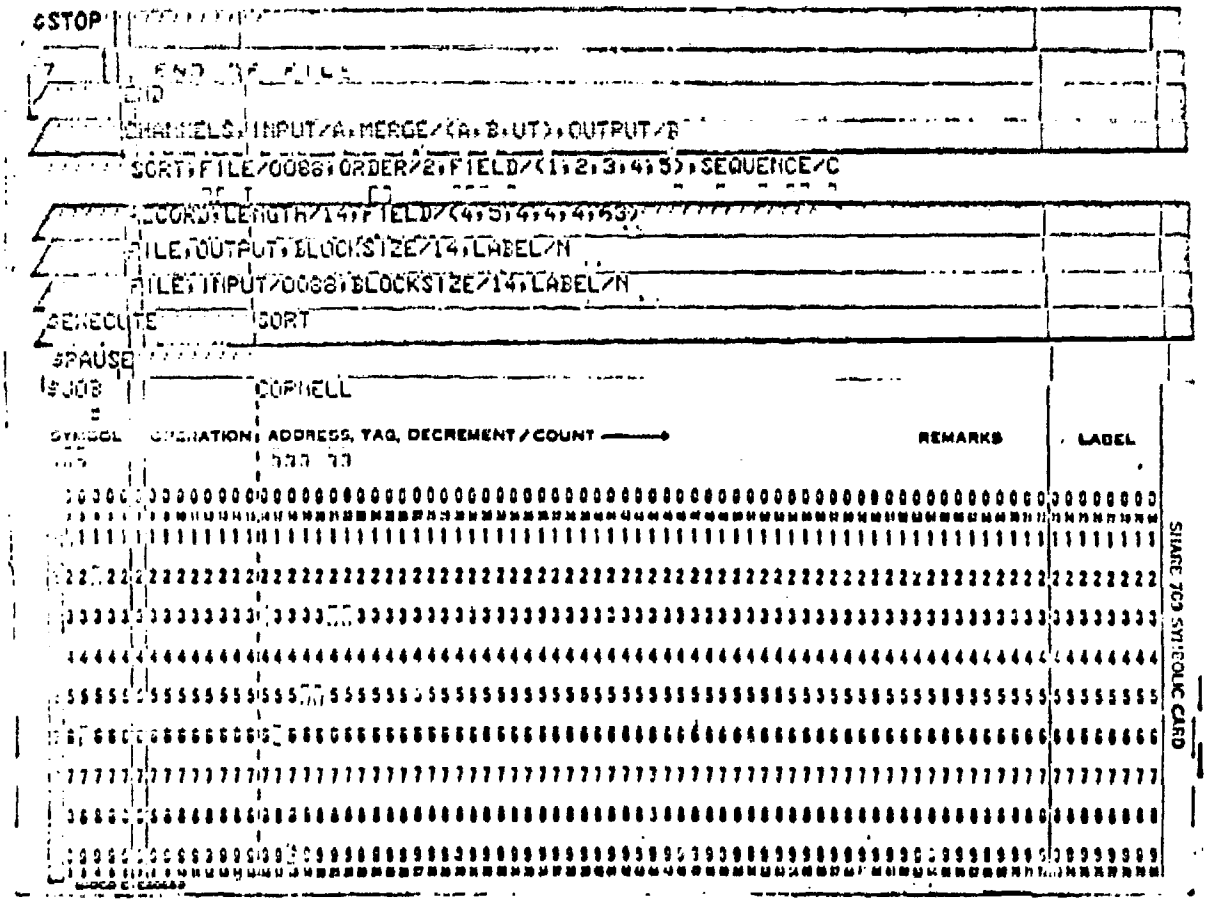
3.1.1 The Inputs

There are three categories of inputs that affect the program; those that control IBSYS, those that control the program and those that provide data to the program. These three types of inputs are provided on four kinds of punched cards: (1) IBSYS Control, (2) Program Control, (3) Data, and (4) Special. These cards are described in the following paragraphs and illustrated in Appendix I and Figures 3-1 through 3-6.

3.1.1.1 IBSYS Control Cards

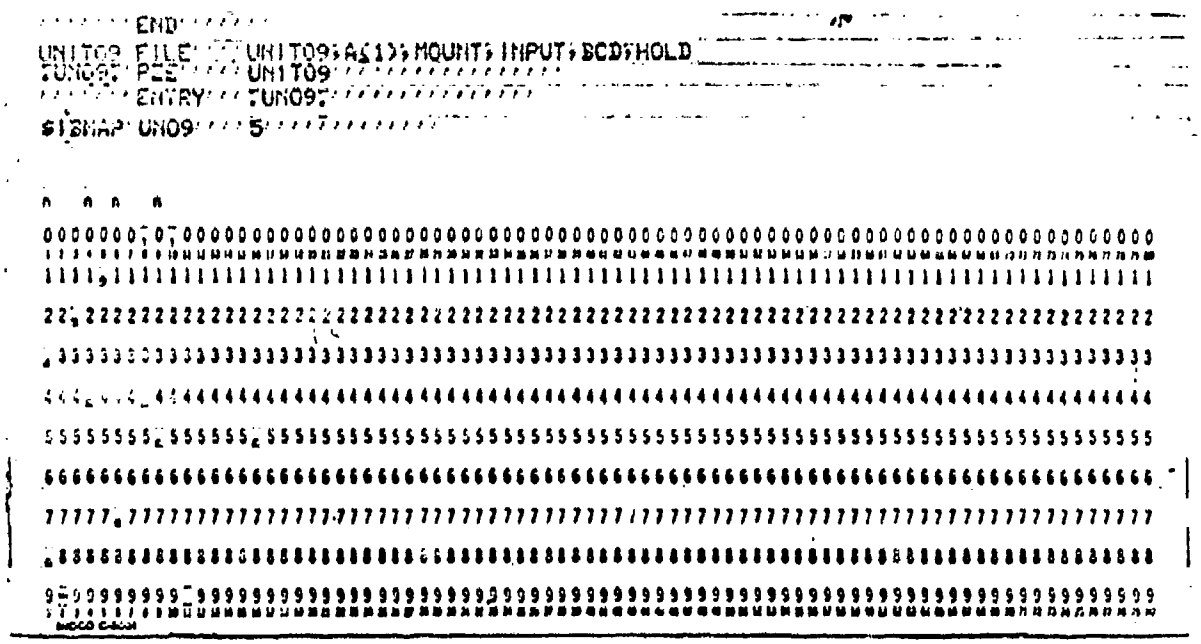
IBSYS is the system which exercises control over the operations conducted by the computer and equipment attached to it. In order for the LRTP Program to operate and to have data for its computations, IBSYS must do these things: (1) Arrange MBPA and WE data in a prescribed order (SORT), (2) establish the arrangement of equipment for the programs use, (3) prepare the program for operation and, (4) allow the program to function.

Figure 3-1 illustrates those cards which cause SORT (a subprogram of IBSYS) to place MBPA and WE data cards in order (see section 3.1.1.3). (For a complete description of SORT see IBM Systems Reference Library File No. 7090-33, entitled, "Generalized Sorting System").



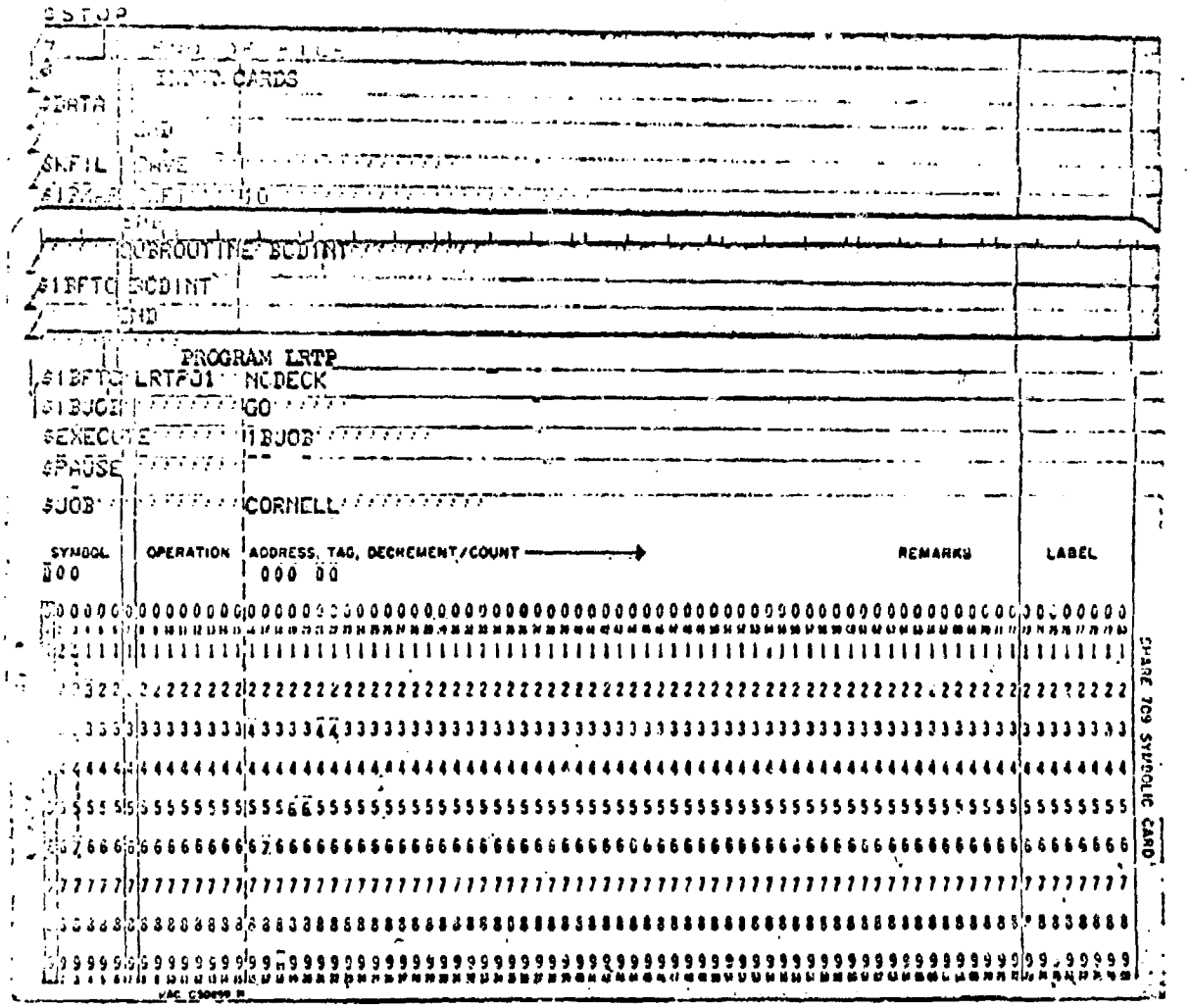
SORT CONTROL CARDS
FIGURE 3-1

* See Appendix I for a description of these fields, on which a commercial SORT is done.



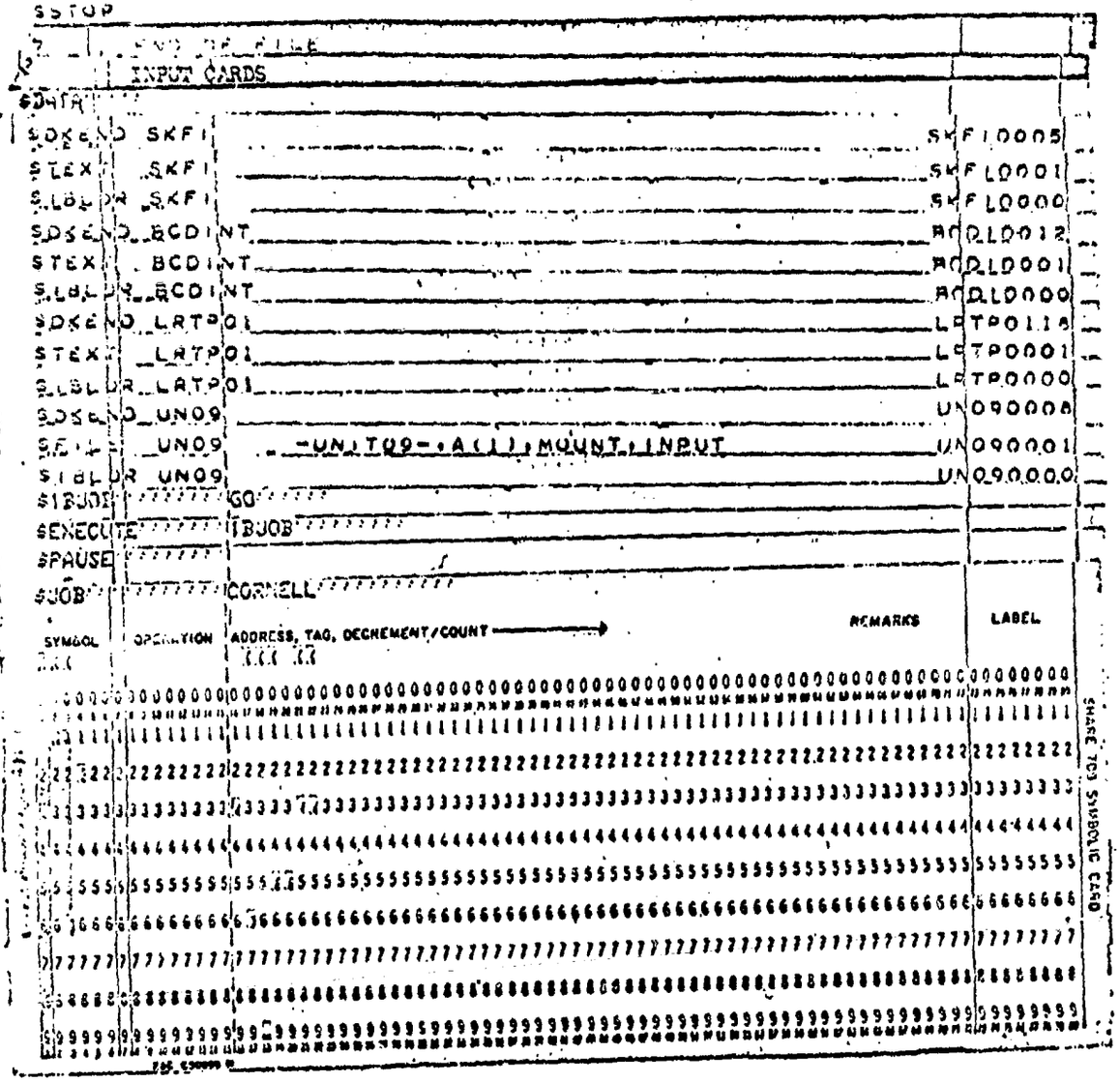
FILE ASSIGNMENT

FIGURE 3-2



CONTROL CARDS TO "COMPILE AND OPERATE"

FIGURE 3-3



CONTROL CARDS TO "LOAD AND OPERATE"

FIGURE 3-4

A program (using the MAP language) is used to add FILE 09 to the dictionary of files that is maintained in IBSYS. This input file (on a magnetic tape) is the sorted MBPA/WE data. Figure 3-2 illustrates this routine.

The FORTRAN IV statements which make up the program are prepared for use by an IBSYS routine called a compiler. The compiler, when the program is free of errors, works in conjunction with another IBSYS routine, called the loader, which organizes the LRTP program and lets it conduct its operations, (see Figure 3-3). NOTE: error free FORTRAN IV statements need not be compiled repeatedly. Once prepared, the "Loader" can use the LRTP program in its prepared form (a binary deck), and compiling need not be done; see Figure 3-4.

A "DATA" card is used to signal the point at which the IBSYS control system shall transfer operations to program LRTP. When LRTP has completed its computations, it relinquishes control to IBSYS (IBJOB Processor) which is directed to cease operations by the "STOP" card.

File No. 7090-27 of the IBM Systems Reference Library, entitled "IBJOB Processor" explains in detail the routines and cards mentioned above.

3.1.1.2 Program Control Cards

Three types of cards influence the operation of the LRTP program. One of them, the "END LRTP" card denotes the end of data on FILE 05, the IBSYS input file. After finding this card, the LRTP program will not seek any more data from FILE 05. For structure of the deck that contains this card see Figure 3-5.

The second kind of control card is the "WE END" card which signifies the end of data on the MBPA/WE file (FILE 09). The sorting process, mentioned in 3.1.1.1, makes this card the last one in the file. The recognition of this card signifies to the program that all data and control cards have been read in. For structure of the deck that contains this card see Figure 3-6.

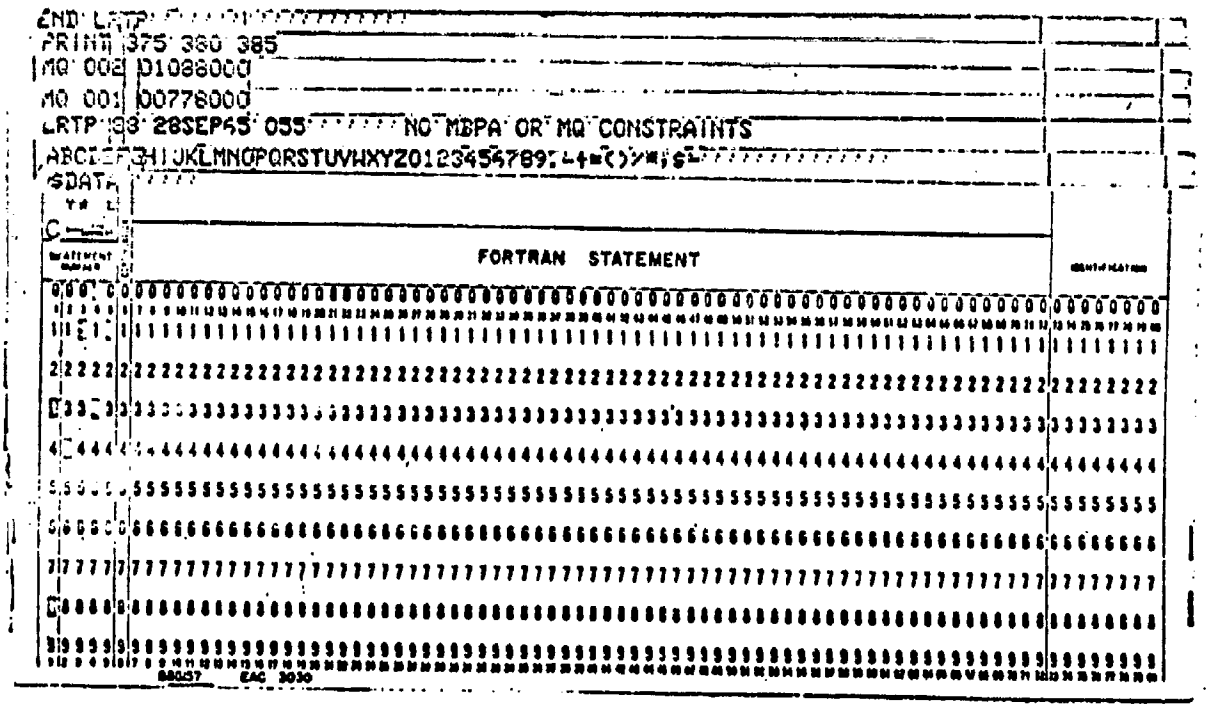
The third control card may or may not be used. It is the "PRINT" card and contains 1 to 16 numbers which specify coordinates. Use it to indicate the Configuration summaries the user wishes to see. A Configuration summary lists the tasks and their costs, by monetary quota, for a coordinate. When used, the card must be placed on FILE 05, somewhere ahead of the "END LRTP" card. For structure of the deck that contains this card see Figure 3-5.

The formats of these three control cards are described in Appendix I.

3.1.1.3 Data Cards

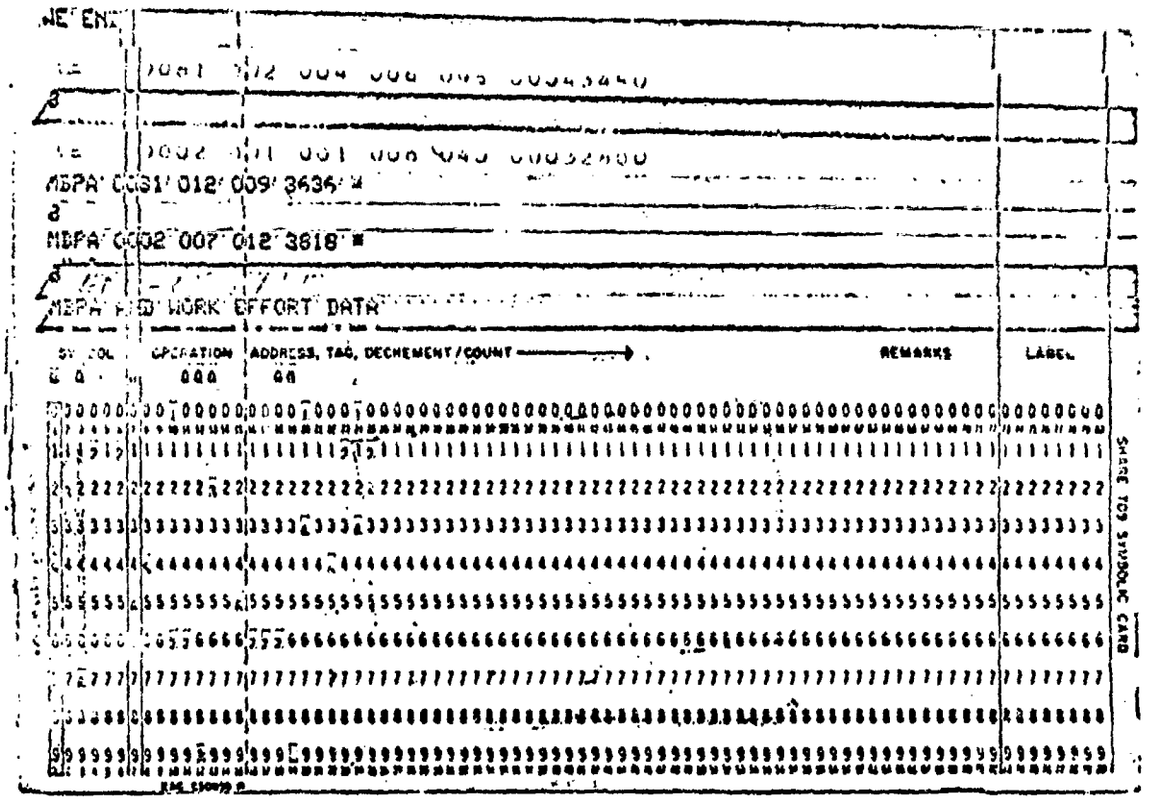
Three kinds of data cards are provided the LRTP program. They contain information about (1) Monetary Quotas (2) Work Efforts and (3) Major Barrier Problem Areas. This information is described in Appendix I. The placement of the MQ cards is illustrated in Figure 3-5, and Figure 3-6 depicts the MBPA and WE cards as they appear in FILE 09 after the operation of SORT. These serve only to provide data to the LRTP program.

See Appendix I for the formats of these cards.



CONTROL AND DATA CARDS FOR FILE 05

FIGURE 3-5



DATA AND CONTROL CARDS FOR FILE 09

FIGURE 3-6

3.1.1.4 Special Cards

It is necessary that three special cards be used. The first of them, the "LRTP" card serves to identify a run of the program, and it also provides one item of information to the program, that item being a count of Research and Development Objectives. See Figure 3-5 for the structure of the deck that contains this card.

A second card, the "BCD Image" card, contains letters, digits and special characters which the program uses when making comparisons. This card must always follow the "$DATA" card. (See Figure 3-5)

Special card three is called the "HEADER" card. It must precede the MBPA/WE cards before they are sorted. The SORT program expects a card of this kind to head the data to be sorted, see Figure 3-6. The sorted MBPA/WE data has the "HEADER" as the first file on the magnetic tape, with the data making up the second file. When processing this file, the LRTP program skips the "HEADER" file.

See Appendix I for the formats of these cards.

3.1.2 The LRTP Program

This section describes how the program reads and uses the control, data and special input cards, makes the calculations specified in the discussion of the model, and provides outputs which reflect the results of its calculations. The flow diagram in Section 3.3 illustrates the movement within the program and the FORTRAN statements in Section 3.4 provide a description of the details in each area of the program. For this section the LRTP program will be discussed from the standpoint of its inputs, its computations and its outputs.

Two categories of tables exist: those that contain data for computations and those that are as buffers (storage of input or output images). The tables of computational data are organized so that there is a relationship between the registers of different tables that pertain to the same subject; i.e., the first registers of MQID, QUOT and BUDG respectively, contain identification, quota and budget for the "MQ" with the lowest ID. Data about "MBPA's" is kept in tables MBNO, MBCD, FREQ, VALU and NODR; and tables NUTE, TECH, PSTE, COST, CSPS, MQNO and DVAL contain information on "TASK's". The MBPA and TASK tables are organized in the same fashion as the MQ tables. Tables IXTE and NOTE are used as storage for indexing data; i.e., data which enables the program to relate a TASK to its MBPA.

Input buffers, tables LPHA, INPT and sometimes IXTE, will contain the code for one card column or one print character per register. Output buffers are set up by the compiler for IOCS, the Input/Output Control System. The LRTP program in its "WRITE" statement specifies the data to be transferred from ITEMS and/or TABLES to the output buffers.

Further detailed explanation may be secured by examination of the FORTRAN listing in Section 3.4.

3.1.2.1 Input Processing

The LRTP program reads in the nine kinds of cards described in Appendix I. With the exception of the "BCD IMAGE" card and the "HEADER" card, field one is tested to ascertain the routine which is to be used to process the card. Once this selection has been made, (if unable to make a selection, see section 3.1.2.1.10) the processing goes as follows:

3.1.2.1.1 "LRTP" Card

(a) Fields 2 and 4 are converted to integers.

(b) Field 2 is saved in register LRTP.

(c) Field 4 is saved in register RDOS.

(d) The contents of the card are written on output FILE 06 (to identify the run of the program for the user).

(e) If an error is found during the conversion, the program transfers to the error routine described in section 3.1.2.1.10, below.

3.1.2.1.2 "PRINT" Card

(a) Up to 16 numbers will be converted to integer form and stored in registers of TABLE IOUT. The numbers must start in Column 7 and be separated by one blank column. Consecutive blank columns are interpreted as signalling the end of the control information. The last column that may be used is number 72.

(b) Errors in converting cause the program to execute the error routine; see section 3.1.2.1.10, below.

3.1.2.1.3 "Monetary Quota" Card

(a) Field 2 is converted to integer and stored in a register of TABLE MQID.

(b) Field 3 is converted to a floating point number and saved in a register ot TABLE QUOT.

(c) Errors in converting these fields cause the program to execute the error routine; see section 3.1.2.1.10, below.

3.1.2.1.4 "END" Card

There is no data on this card. Its recognition, however, causes the program to arrange the MQID and QUOT tables in ascending order of MQ identification. In addition, an indicator, MBTK, is set which informs the program that all card reading is now to be done from FILE 09. Several items and tables are cleared in preparation for information from the data cards.

3.1.2.1.5 "MBPA" Card

(a) Field 2 is converted to integer and stored in a register of TABLE MBNO.

(b) Field 3 is converted from a BCD percentage to a floating point decimal and stored in a register of FREQ.

(c) Field 4 is converted to a floating point number, divided by item RDOS, multiplied by the contents of a register of FREQ (from field 3) and this product stored in this register of FREQ.

(d) Field 5 is converted to a floating point number, multiplied by the contents of FREQ (from (c) above) and the product stored in this register of FREQ.

(e) Field 6 is tested for a blank; if it contains a blank, a register of MBCD is set to blanks; otherwise, the register is set to an asterisk (*).

(f) For errors in fields 2, 3, 4 or 5, see section 3.1.2.1.10, below.

3.1.2.1.6 "WE" Card

(a) Fields 2, 3, 4 and 5 are converted to integers and stored in IDMB, IDTE, IDWE and IDMQ respectively.

(b) Fields 6 and 7 are converted to floating point and stored in PSTK and CSWE respectively. If the annual Work Effort is for the first year, the contents of field 7 are stored in CSTK, also.

(c) The program now uses the information in the items listed in (a) and (b), above, to place the following data in their proper locations in these tables:

(1) NOTE = Count of TASKS in a MBPA
(2) IXTE = Index to TASK information for a MBPA
(3) NUTE = TASK Id
(4) PSTE = Product of the probabilities of success of the WORK EFFORTS in a TASK
(5) COST = First year cost of a TASK
(6) CSPS = Expected cost of a TASK
(7) MQNO = MONETARY QUOTA which contains cost of TASK

(d) For errors in fields 2 through 7, see section 3.1.2.1.10, below.

3.1.2.1.7 "WE END" Card

When the program finds this card, it transfers its operations from reading input data to doing the computations stated in the discussion of the LRTP MODEL in Section 2.

3.1.2.1.8 "BCD IMAGE" Card

The program must have this card prior to operating on any other input. Therefore, this card must follow the "$DATA" card (see Figure 3-5). The first 48 characters are stored in TABLE LPHA. The data on this card must be correct and in the prescribed order, as tests for the correctness of other input data are made using "BCD IMAGE" information as the criterion.

3.1.2.1.9 "HEADER" Card

When the program begins to read from FILE 09, it executes two "read" instructions, one is to by-pass this card; the second to by-pass the "END-OF-FILE" mark. The only purpose this card serves is to satisfy the rules by which the SORT program operates.

3.1.2.1.10 Errors

An error in a piece of input information results in no computations. The program, however, prints the card which contains the error and examines all input data for illegalities, printing the cards with erroneous data.

3.1.2.2 The Calculations

There are two major areas of computation in the LRTP program. The first calculates the Technical Value of each Task and, using this TV and the Expected Cost of the Task, establishes their order of elimination. The second takes each Task, in the order that has

been set, and examines it in relation to the constraints (MBPA and MQ) that are to apply for this run of the program. When a Task is to be eliminated, the program enters the output section (see Section 3.1.2.3, below). After recording what is required in the output section, the program returns to examine the next Task in line against the constraints.

The details of the two areas of computation are as follows:

3.1.2.2.1 Technical Value

The LRTP program computes first the cost of the program being considered and then its Technical Value. Cost is the sum of the first year costs of all Tasks; Technical Value is the sum of the Technical Values of all MBPA's.

Secondly, a number which signifies relative importance is attached to each Task by computing its TV and dividing that figure by its Expected Cost (CSPS). The results are saved in the Table TECH.

3.1.2.2.2 Constraints

The Task with the least importance attached to it is examined according to rules that pertain to MBPA elimination and satisfaction of Monetary Quotas. If the Task can be eliminated without violating any MBPA or MQ rules, it is removed from the list of Tasks; and appropriate action is taken in the Output section. Whether a Task is removed or not, the next Task considered for removal is the one with the next lowest ratio of Technical Value to Expected Cost; and so on, through all Tasks.

The rules which the program contains have to do with setting a value on each Monetary Quota and not permitting the elimination of a Task to reduce a Quota below this value; and, stating whether or not all the Tasks in a MBPA may be eliminated.

3.1.2.3 The Outputs

When the LRTP program selects a Task to be eliminated, it enters the area of the program which will record for the user the pertinent information about the removal of the Task.

3.1.2.3.1 Run Information

However, three kinds of information have been written on the output file (FILE 06) prior to selecting Tasks for removal. The first of these is the Run Identification which is merely writing on the output file, the contents of the LRTP card. The second kind of information is a list of MBPA's, by ID, together with the indication of whether a MBPA can be eliminated. The third is a list of Monetary Quotas, by ID, with the number of dollars assigned to each.

The formats of these three types of output are illustrated in Figure 3-7.

3.1.2.3.2 Run Results

Illustrated in Figure 3-8 is the chart produced by the LRTP program as Tasks are eliminated. As each Task is removed, the charges in Technical Value and in Cost are printed, as well as the data which identifies the MBPA, TASK and Coordinate.

```
LRTP 88 29SEP65 055        75 PER CENT MQ     RETAIN 30 MBPAS
```

LRTP IDENTIFICATION

```
FOLLOWING IS A LIST OF MBPA(S) FOR THIS RUN OF THIS PROGRAM. THOSE PRECEDED BY ASTERISKS CANNOT BE
( )   1  (*)   2  (*)   3  ( )   4  ( )   5  ( )   6  (*)   7  ( )   8  (*)   9  ( )  10  (*)  11
( )  14  ( )  15  ( )  16  (*)  17  (*)  18  ( )  19  ( )  20  ( )  21  ( )  22  ( )  23  ( )  24
(*)  27  ( )  28  ( )  29  (*)  30  ( )  31  ( )  32  ( )  33  ( )  34  ( )  35  ( )  36  (*)  37
( )  40  ( )  41  ( )  42  ( )  43  (*)  44  ( )  45  (*)  46  ( )  47  ( )  48  ( )  49  ( )  50
( )  53  ( )  54  (*)  55  ( )  56  ( )  57  ( )  58  (*)  59  (*)  60  ( )  61  ( )  62  ( )  63
( )  66  ( )  67  ( )  68  ( )  69  ( )  70  (*)  71  ( )  72  ( )  73  ( )  74  ( )  75  ( )  76
(*)  79  ( )  80  ( )  81  ( )  82  ( )  83  ( )  84  ( )  85  ( )  86  (*)  87  ( )  88  ( )  89
( )  92  ( )  93  ( )  94  ( )  95  ( )  96  (*)  97  (*)  98  ( )  99  ( ) 100  ( ) 101  ( ) 102
( ) 105  ( ) 106  ( ) 107  ( ) 108  (*) 109  ( ) 110  ( ) 111  ( ) 112  ( ) 113  ( ) 114  ( ) 115
( ) 118  ( ) 119  ( ) 120  ( ) 121  ( ) 122  (*) 123  ( ) 124  ( ) 125  ( ) 126  ( ) 127  (*) 128
( ) 131  ( ) 132  ( ) 133  ( ) 134  ( ) 135  ( ) 136  (*) 137  ( ) 138  (*) 139  ( ) 140  ( ) 141
( ) 144  ( ) 145  (*) 146  ( ) 147  ( ) 148  ( ) 149  ( ) 150  (
```

MBPA SUMMARY

```
FOLLOWING IS A LIST OF MONETARY QUOTAS WITH THE NUMBER OF DOLLARS IN EACH.
1 $ 990000.*   2 $1200000.*   3 $1110000.*   4 $1140000.*   5 $1500000.*   6 $1110000.*   7 $11100
9 $ 960000.*  10 $ 870000.*
```

MQ SUMMARY

OUTPUT FORMATS

FIGURE 3-7

COORDINATE NUMBER	TASK ELIMINATED * NODE	TASK	TECHNICAL VALUE * TOTAL	DELTA	COST * TOTAL	DELTA	* NODE
1	NONE	NONE	6454.537	NONE	$ 15016950.	$ NONE	NONE
2	24	2	6454.533	0.004	14984950.	32000.	0
3	56	1	6454.528	0.006	14946600.	38350.	0
4	24	4	6454.525	0.003	14914950.	31650.	0
5	130	4	6454.515	0.010	14880750.	34200.	0
6	50	4	6454.507	0.008	14837650.	43100.	0
7	59	2	6454.500	0.008	14807650.	30000.	0
8	120	3	6454.488	0.011	14767000.	40650.	0
9	50	3	6454.470	0.019	14728350.	38650.	0
10	30	4	6454.454	0.016	14696100.	32250.	0
11	140	2	6454.435	0.019	14662200.	33900.	0
12	64	1	6454.417	0.018	14629850.	32350.	0
13	40	2	6454.401	0.016	14597200.	32650.	0
14	7	4	6454.378	0.023	14557900.	39300.	0
15	56	2	6454.357	0.022	14521350.	36550.	0
16	121	3	6454.325	0.031	14483150.	38200.	0
17	92	1	6454.286	0.039	14445850.	37300.	0
18	33	2	6454.252	0.034	14409550.	36300.	0
19	27	1	6454.213	0.040	14378700.	30850.	0
20	139	3	6454.178	0.035	14347700.	31000.	0
21	51	2	6454.151	0.027	14314950.	32750.	0
22	74	2	6454.109	0.042	14284150.	30800.	0
23	2	2	6454.071	0.038	14248700.	35450.	0
24	139	1	6454.025	0.045	14214400.	34300.	0
25	40	2	6453.981	0.044	14182200.	32200.	0
26	34	3	6453.916	0.065	14146600.	35600.	0
27	142	1	6453.857	0.059	14107150.	39450.	0
28	2	3	6453.799	0.058	14076150.	31000.	0
29	34	1	6453.697	0.102	14029300.	46850.	0
30	44	2	6453.621	0.076	13986000.	43300.	0
31	40	3	6453.552	0.069	13944350.	41650.	0
32	117	2	6453.492	0.061	13905200.	39150.	0
33	1	1	6453.435	0.057	13874550.	30650.	0
34	3	2	6453.345	0.089	13842750.	31800.	0
35	23	1	6453.292	0.054	13804050.	38700.	0
36	44	4	6453.196	0.095	13768550.	35500.	0
37	51	1	6453.109	0.087	13735950.	32600.	0
38	143	4	6452.992	0.117	13697550.	38400.	0
39	88	4	6452.868	0.124	13663350.	34200.	0
40	85	3	6452.640	0.228	13624650.	38700.	0

TASK ELIMINATION CHART

FIGURE 3-8

3.1.2.3.3 Coordinate Configuration

When the "PRINT" card is an input, the data illustrated in Figure 3-9 will result. This lists, according to Monetary Quota, those TASKS which make up the R&D program at the coordinate(s) specified on the "PRINT" card.

In operation, the program examines Table IOUT each time a Task is removed. When it finds that a summary has been requested for a coordinate, the program writes the information on FILE 08. Upon completing the examination of all Tasks, the Configuration summaries are transferred from FILE 08 to FILE 06 so that all information produced by the LRTP program can be printed from one magnetic tape.

3.1.2.4 Using the LRTP Program

Listed below are the steps to be taken in using the program. The list shows all steps. Steps that cannot be by-passed are flagged by an asterisk.

(a) SORT MBPA/WE Cards
*(b) Load program decks,control cards and data cards on Tape
*(c) Place MBPA/WE tape on FILE 09
*(d) Place tape from (b) on FILE 05
*(e) Place blank tape on FILE 06
(f) Place blank tape on FILE 08
(g) Compile "FILE ASSIGNMENT" subroutine deck
(h) Compile "LRTP" program deck
(i) Compile "BCDINT" subroutine deck
(j) Compile "SKFIL" subroutine deck

```
CONFIGURATION OF COORDINATE      1
  MC   1        MC   2        MQ   3        MC   4        MQ   5        MC   6        MC   7        MC   8
$       0.     $       0.     $       0.     $       0.     $       0.     $       0.     $   50000.     $       0.
 ******         ******         ******         ******         ******         ******         ******         ******

 MBPA TASK      MBPA TASK      MBPA TASK      MBPA TASK      MBPA TASK      MBPA TASK      MBPA TASK      MBPA TASK
 ******         ******         ******         ******         ******         ******         ******         ******
   1   2          2   3          6   1          3   2          3   1          2   1          1   1          3   3
$   35400.     $   31000.     $   32400.     $   31800.     $   41500.     $   32800.     $   30650.     $   45550.
   2   2          2   4         10   2          4   2          4   1          3   4          5   1          7   1
$   35450.     $   30100.     $   46150.     $   41250.     $   45900.     $   30450.     $   39900.     $   44600.
                                             7   4          5   2          8   2          7   2          9   3
                                         $   39300.     $   36400.     $   35300.     $   35900.     $   45100.
                                             9   4          7   3         10   1          9   2
                                         $   39400.     $   40700.     $   36750.     $   37050.
                                                            8   1         10   3
                                                        $   38100.     $   32900.
                                                           10   4
                                                        $   42450.

 ******         ******         ******         ******         ******         ******         ******         ******
 TOTAL          TOTAL          TOTAL          TOTAL          TOTAL          TOTAL          TOTAL          TOTAL
$   70850.     $   124400.    $   78550.     $   151750.    $   245050.    $   168200.    $   143750.    $   135250.
 ******         ******         ******         ******         ******         ******         ******         ******

END OF COORDINATE    1
```

SUMMARY OF CONFIGURATIONS

OUTPUT FORMAT

FIGURE 3-9

*(k) Load "FILE ASSIGNMENT" deck

*(l) Load "LRTP" deck

*(m) Load "BCDINT" deck

*(n) Load "SKFIL" deck

*(o) At this point, whatever course has been followed above, the LRTP program operates on data from FILES 05 and 09, recording information on FILES 06 and 08 (if requested), according to control information on FILES 05 and 09. Upon completion of program operation:

*(p) Print FILE 06

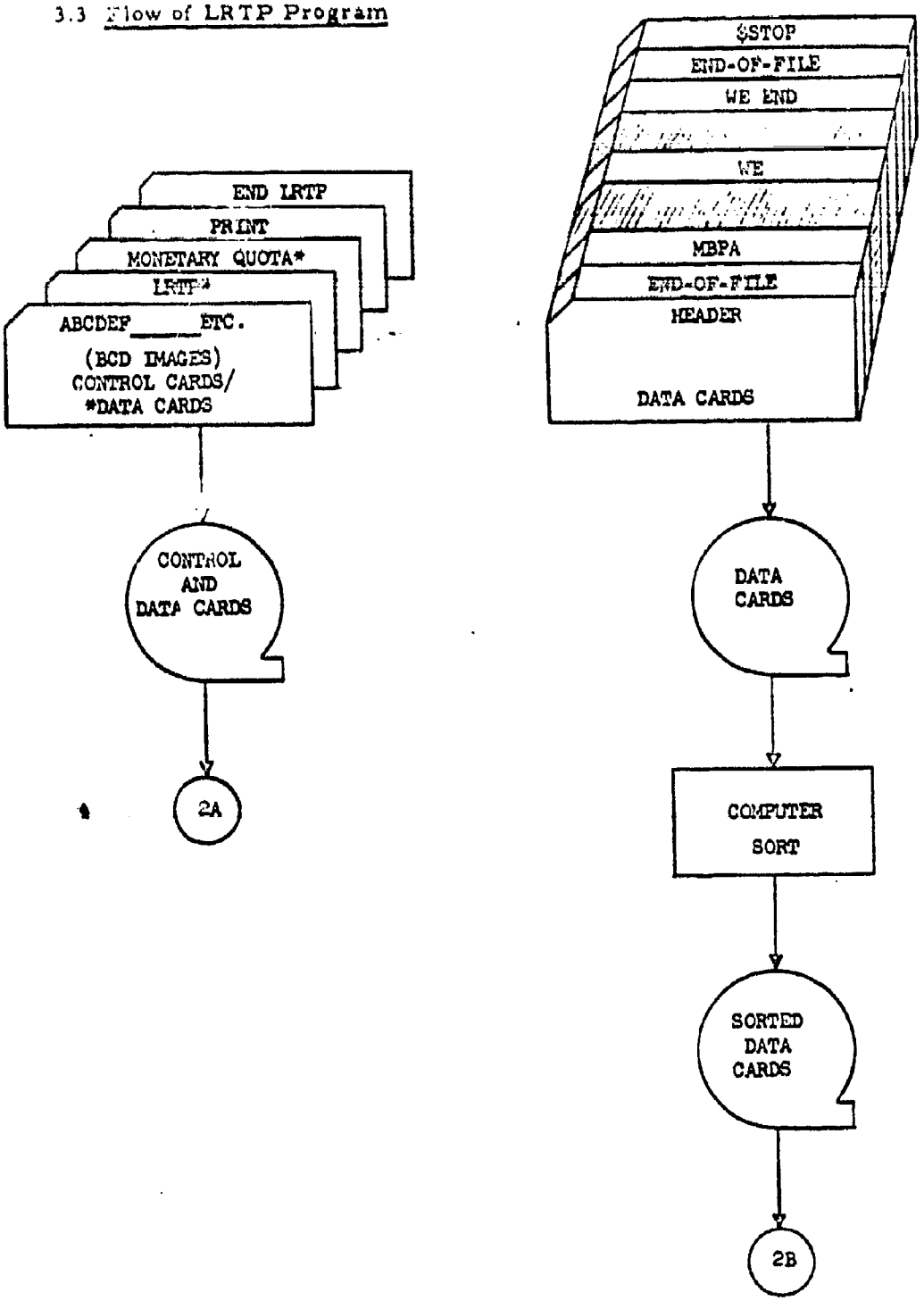
3.2 Definition of TABLES and ITEMS

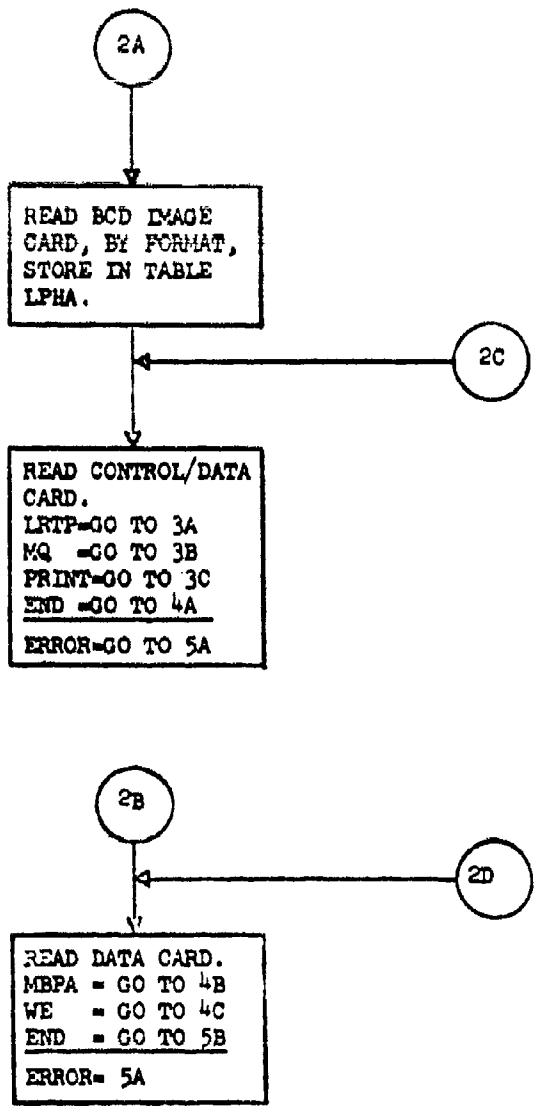
Listed below are terms used in the LRTP program. The definitions attached to these terms reflect, where appropriate, the symbols used in Section 2, Mathematical Description of LRTP Model.

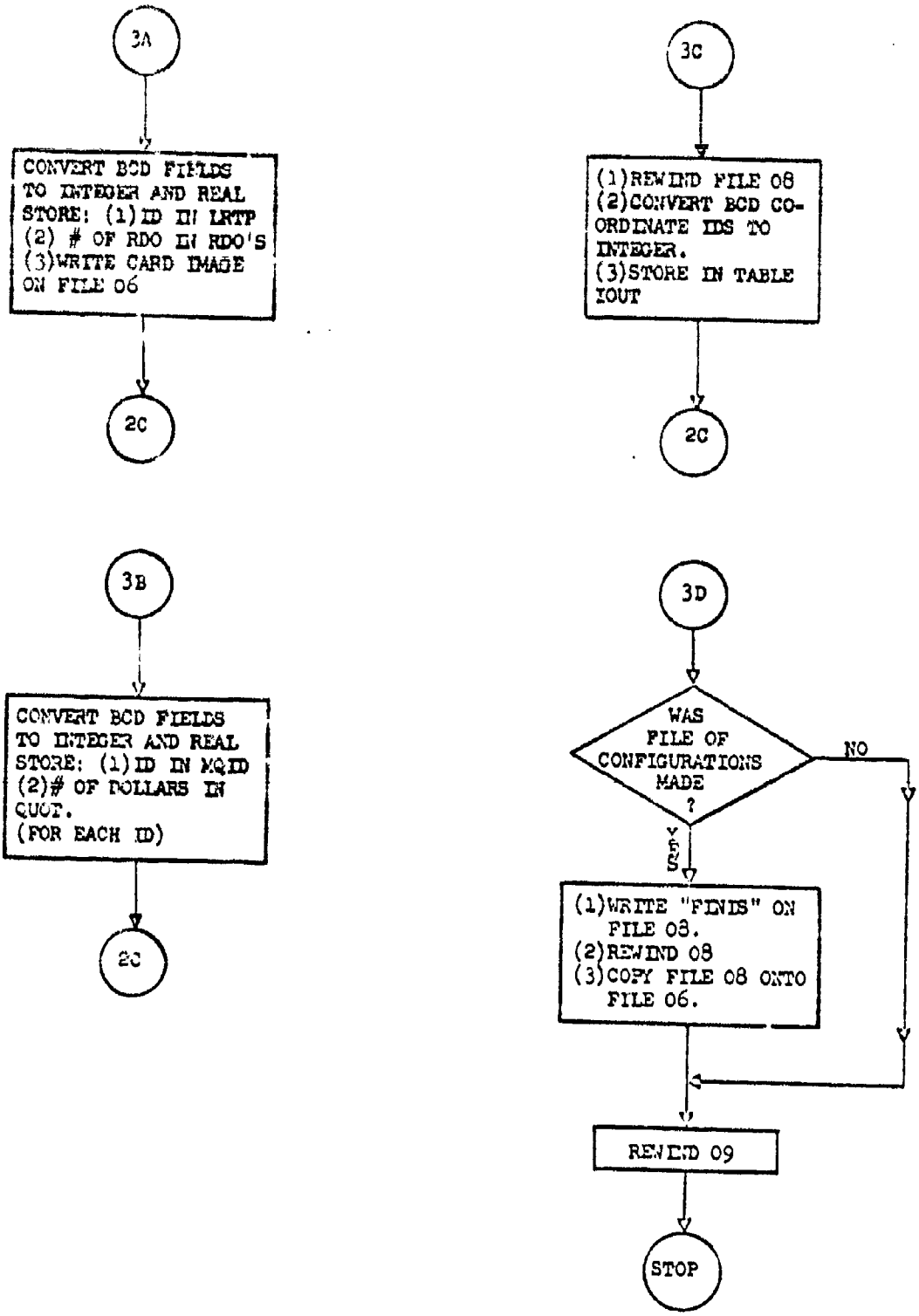
VALU	=	table of technical values of MBPA's, $V_k(r_k)$
COST	=	table of first year costs of TASKS, C_{jk}
NUTE	=	table of identification numbers of TASKS, (j)
CSPS	=	table of expected costs of TASKS, $E_{jk}(r_{jk})$
PSTE	=	table of probabilities of success of TASKS, $P_{jk}(r_{jk})$, or table of probabilities of failure of TASKS $N_{jk}(r_{jk})$
TECH	=	table of ratios V_{jk}/E_{jk}
DVAL	=	table of values of V_{jk}
MQNO	=	table of the Monetary Quota number of the first WE of the TASK
TCST	=	annual cost C(r) of a Configuration
TVAL	=	technical value V(r) of a Configuration
MBNO	=	table of identification numbers of MBPA's k=1, 2, ..., a ≤ 9999

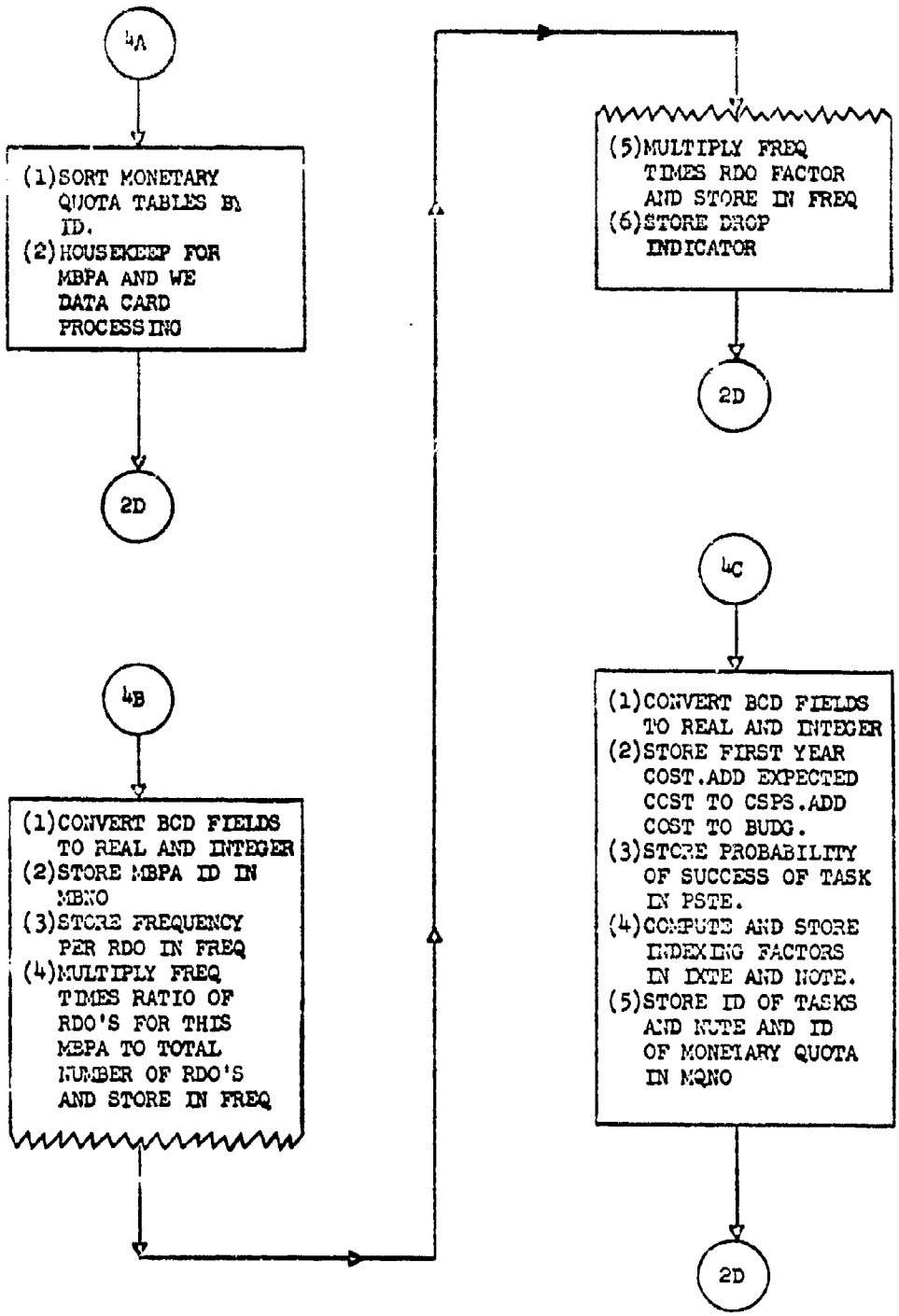
FREQ	=	table of values of $w_k e_k U_k$
MBCD	=	table of values of h_k where; h_k = *: denotes the MBPA cannot be dropped; h_k = blank: denotes the MBPA can be dropped
NOTE	=	table of count of TASKS in each MBPA, d_k
QUOT	=	table of minimum funds that must be allocated to each Monetary Quota $F = (f_1, f_2, \ldots, f_n, \ldots, f_b)$ where $b < 1000$ and number of MQ's ≤ 100
MQID	=	table of identification numbers of Monetary Quotas $N = (n_x, n_y, \ldots, n_z)$ where x, y, z $\leq$ 999 and number of N(s) $\leq$ 100; and no n equals another
BUDG	=	table of Monetary Quota Cost of a Configuration, $Q(r) = (q_1, q_2, \ldots, q_b)$
IXTE	-	Table of factors for setting indexes in tables that contain information about Tasks
NODR	-	Table where a count is maintained of the Tasks eliminated from a MBPA
LPHA	-	Table of the representations of letters, digits and special characters
INPT	-	Table into which card images are read
IOUT	-	Table in which cocrdinate numbers are stored.

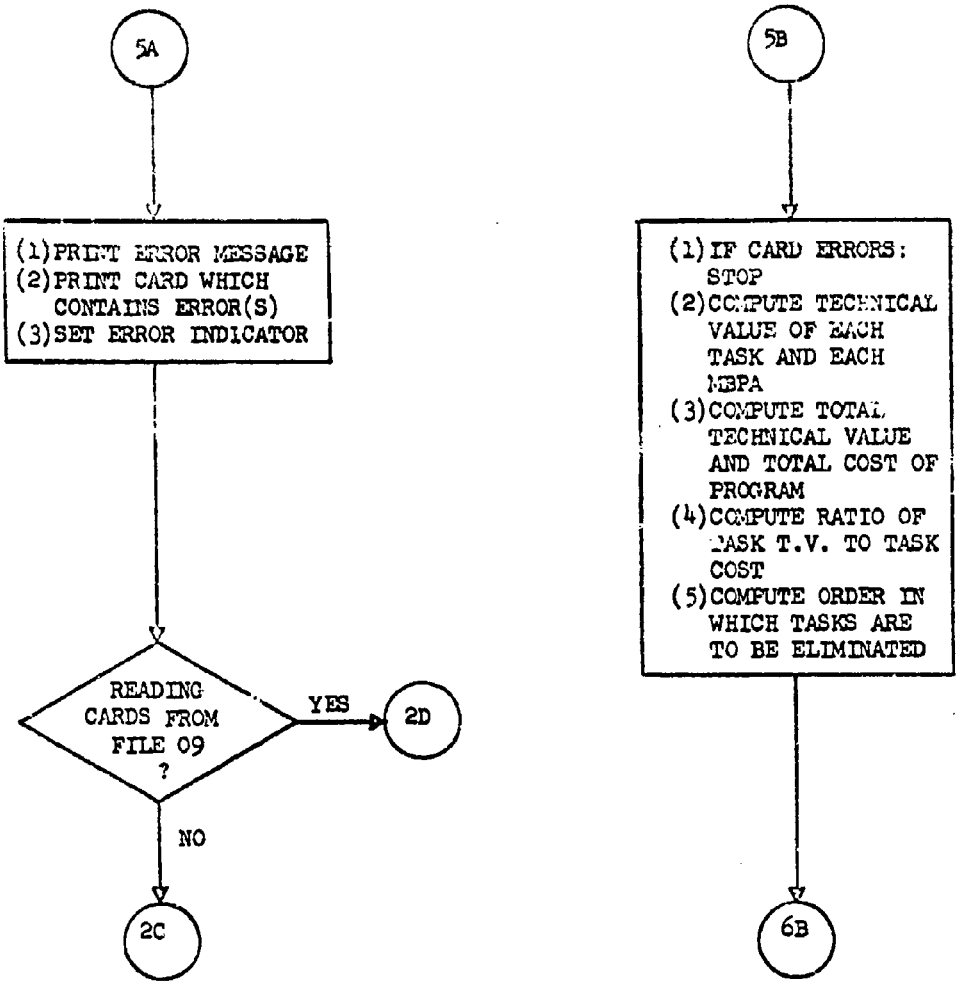
3.3 Flow of LRTP Program

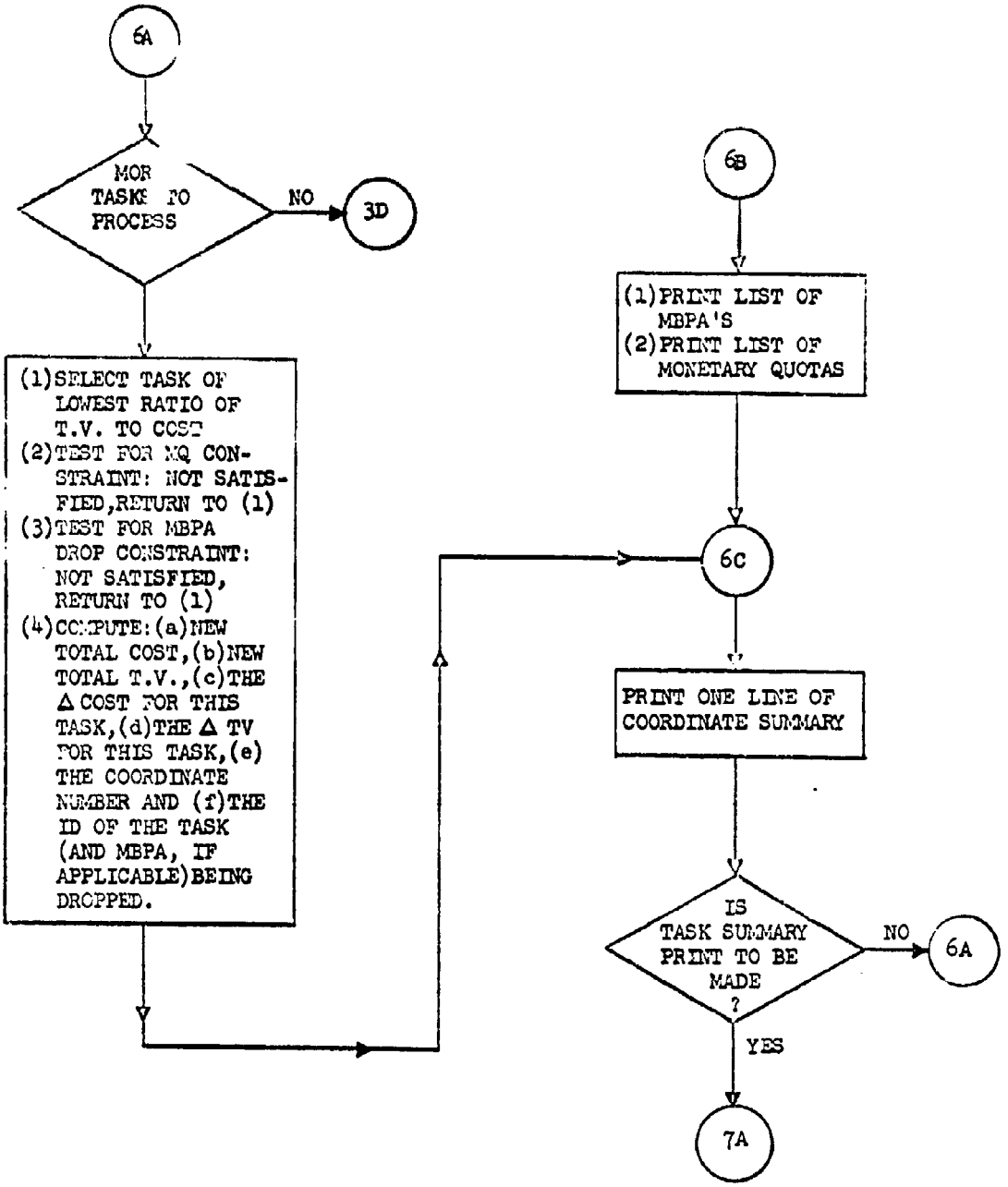


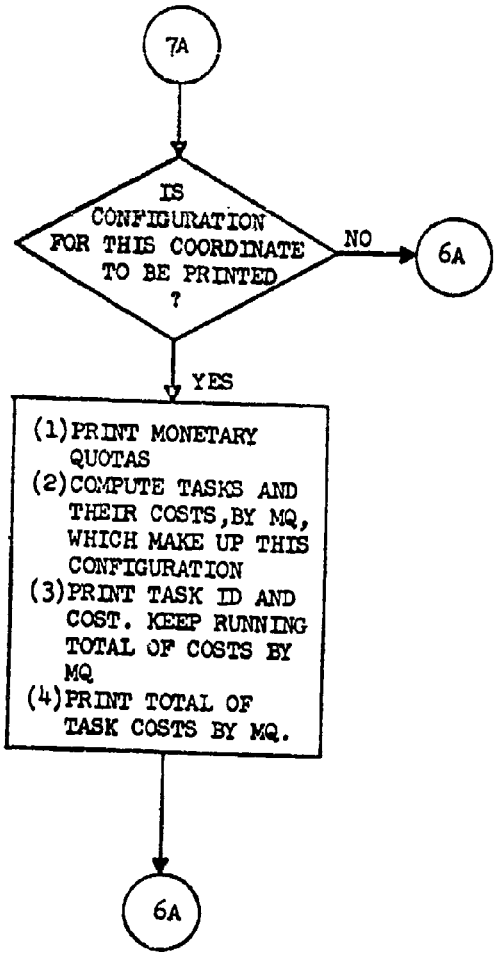

2A
READ BCD IMAGE CARD, BY FORMAT, STORE IN TABLE LPHA.
2C
READ CONTROL/DATA CARD.
LRTP=GO TO 3A
MQ =GO TO 3B
PRINT=GO TO 3C
END =GO TO 4A
ERROR=GO TO 5A
2B
2D
READ DATA CARD.
MBPA = GO TO 4B
WE = GO TO 4C
END = GO TO 5B
ERROR= 5A


3A
CONVERT BCD FIELDS TO INTEGER AND REAL STORE: (1) ID IN LRTP (2) # OF RDO IN RDO'S (3)WRITE CARD IMAGE ON FILE 06
2C
3C
(1)REWIND FILE 08 (2)CONVERT BCD CO-ORDINATE IDS TO INTEGER. (3)STORE IN TABLE IOUT
2C
3B
CONVERT BCD FIELDS TO INTEGER AND REAL STORE: (1) ID IN MQID (2)# OF DOLLARS IN QUOT. (FOR EACH ID)
2C
3D
WAS FILE OF CONFIGURATIONS MADE ?
NO
YES
(1)WRITE "FINIS" ON FILE 08. (2)REWIND 08 (3)COPY FILE 08 ONTO FILE 06.
REWIND 09
STOP


4A
(1)SORT MONETARY QUOTA TABLES BY ID.
(2)HOUSEKEEP FOR MBPA AND WE DATA CARD PROCESSING
2D
4B
(1)CONVERT BCD FIELDS TO REAL AND INTEGER
(2)STORE MBPA ID IN MBNO
(3)STORE FREQUENCY PER RDO IN FREQ
(4)MULTIPLY FREQ TIMES RATIO OF RDO'S FOR THIS MBPA TO TOTAL NUMBER OF RDO'S AND STORE IN FREQ
(5)MULTIPLY FREQ TIMES RDO FACTOR AND STORE IN FREQ
(6)STORE DROP INDICATOR
2D
4C
(1)CONVERT BCD FIELDS TO REAL AND INTEGER
(2)STORE FIRST YEAR COST.ADD EXPECTED COST TO CSPS.ADD COST TO BUDG.
(3)STORE PROBABILITY OF SUCCESS OF TASK IN PSTE.
(4)COMPUTE AND STORE INDEXING FACTORS IN INTE AND NOTE.
(5)STORE ID OF TASKS AND NOTE AND ID OF MONETARY QUOTA IN MQNO
2D


5A
(1)PRINT ERROR MESSAGE
(2)PRINT CARD WHICH CONTAINS ERROR(S)
(3)SET ERROR INDICATOR
READING CARDS FROM FILE 09 ?
YES
2D
NO
2C
5B
(1)IF CARD ERRORS: STOP
(2)COMPUTE TECHNICAL VALUE OF EACH TASK AND EACH MBPA
(3)COMPUTE TOTAL TECHNICAL VALUE AND TOTAL COST OF PROGRAM
(4)COMPUTE RATIO OF TASK T.V. TO TASK COST
(5)COMPUTE ORDER IN WHICH TASKS ARE TO BE ELIMINATED
6B


6A
MOR TASKS TO PROCESS
NO
3D
(1)SELECT TASK OF LOWEST RATIO OF T.V. TO COST
(2)TEST FOR MQ CONSTRAINT: NOT SATISFIED,RETURN TO (1)
(3)TEST FOR MBPA DROP CONSTRAINT: NOT SATISFIED, RETURN TO (1)
(4)COMPUTE:(a)NEW TOTAL COST,(b)NEW TOTAL T.V.,(c)THE Δ COST FOR THIS TASK,(d)THE Δ TV FOR THIS TASK,(e) THE COORDINATE NUMBER AND (f)THE ID OF THE TASK (AND MBPA, IF APPLICABLE)BEING DROPPED.
6B
(1)PRINT LIST OF MBPA'S
(2)PRINT LIST OF MONETARY QUOTAS
6C
PRINT ONE LINE OF COORDINATE SUMMARY
IS TASK SUMMARY PRINT TO BE MADE ?
NO
6A
YES
7A


7A
IS CONFIGURATION FOR THIS COORDINATE TO BE PRINTED ?
NO
6A
YES
(1)PRINT MONETARY QUOTAS
(2)COMPUTE TASKS AND THEIR COSTS,BY MQ, WHICH MAKE UP THIS CONFIGURATION
(3)PRINT TASK ID AND COST. KEEP RUNNING TOTAL OF COSTS BY MQ
(4)PRINT TOTAL OF TASK COSTS BY MQ.
6A

3.4 Fortran Listing

EXTERNAL FORMULA NUMBER - SOURCE STATEMENT

```
      COMMON LPHA(44),INPT(072),INCH,NOCH,INTG,IERR,INTI
      COMMON IXTE(500),IPTI,IPCH,NPCH,IPTG,IPRR
      DIMENSION BUDG(100),MQID(100),QUOT(100),FREQ(500),MBNO(500),
     2MBCD(500),NODR(500),NOTE(500),VALU(500),COST(1500),CSPS(1500),
     3NUTE(1500),PSTE(1500),TECH(1500),DVAL(1500),IOUT(16),
     4MQNO(1500),CBUF(10),CMQT(10),KBUF(10),MBUF(10)
      REWIND 9
      I = 0
      INER = 0
      MBTK = 0
      LRCD = 0
      DO 104 J = 1,100
      MQID(J) = 0
      QUOT(J) = 0.
      BUDG(J) = 0.
  104 CONTINUE
      READ (5,190) (LPHA(N),N=1,43)
  100 READ (5,191) (INPT(N),N=1,72)
      IF (INPT(1).EQ.LPHA(13)) GO TO 140
      IF (INPT(1).EQ.LPHA(12)) GO TO 130
      IF (INPT(1).EQ.LPHA(16)) GO TO 500
      IF (INPT(1).EQ.LPHA(5)) GO TO 200
      GO TO 180
  102 READ (9,191) (INPT(N),N=1,72)
      CALL SKFIL
  101 READ (9,191) (INPT(N),N=1,72)
      IF (INPT(1).EQ.LPHA(23)) GO TO 110
      IF (INPT(1).EQ.LPHA(13)) GO TO 120
      GO TO 180
  110 IF (INPT(4).EQ.LPHA(5)) GO TO 300
      INCH =6
      NOCH = 4
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      IDMB =INTG
      INCH = 11
      NOCH=3
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      IDTE = INTG
      INCH = 15
      NOCH = 3
      CALL BCDINT
      IF (IERR .EQ. 1) GO TO 180
      IDWE = INTG
      INCH = 19
      NOCH = 3
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      IDMO = INTG
      INCH = 23
      NOCH = 3
      CALL BCDINT
      IF (IERR.EQ.1)GO TO 180
      PSTK = INTG
```

```
      EXTERNAL FORMULA NUMBER   -   SOURCE STATEMENT

     PSTK =PSTK/100.
     INCH = 27
     NOCH = 8
     CALL BCDINT
     IF (IERR.EQ.1) GO TO 180
     CSWE = INTG
     IF (IDWE .GT. 1) GO TO 103
     CSTK = CSWE
     DO 30  JK = 1,IENT
     IF (MQID(JK).NE.IDMQ) GO TO 30
     BUDG(JK) = BUDG(JK) + CSTK
     GO TO 109
  30 CONTINUE
     GO TO 180
 103 CSTK = 0.
 109 IF (LMID.EQ.IDMB.AND.LTID.EQ.IDTE) GO TO 111
     IF (LMID.EQ.IDMB.AND.LTID.NE.IDTE) GO TO 112
     K = K + 1
     DO 31 M = 1,JENT
     IF(MBNO(M).NE.IDMB) GO TO 31
     NOTE(M) = 1
     IXTE(M) = K
     GO TO 106
  31 CONTINUE
     GO TO 180
 106 LMID = IDMB
 113 LTID = IDTE
     NUTE(K) = IDTE
     PSTE(K) = PSTK
     COST(K) = CSTK
     CSPS(K) = CSWE
     MQNO(K) = IDMQ
     GO TO 101
 112 K = K + 1
     NOTE(M) = NOTE(M) + 1
     GO TO 113
 111 PSTE(K) = PSTE(K)*PSTK
     CSPS(K) = CSWE*PSTK + CSPS(K)
     GO TO 101
 120 INCH = 6
     NOCH = 4
     CALL BCDINT
     IF (IERR.EQ.1) GO TO 180
     J = J + 1
     JENT = J
     MBNO(J) = INTG
     INCH = 11
     NOCH = 3
     CALL BCDINT
     IF (IERR.EQ.1) GO TO 180
     FREQ(J) = INTG
     FREQ(J) = FREQ(J)/100.
     INCH = 15
     NOCH = 3
     CALL BCDINT
     IF (IERR.EQ.1) GO TO 130
```

```
      EXTERNAL FORMULA NUMBER   -   SOURCE STATEMENT

      PARD = INTG
      FREQ(J) = (PARD/RDOS)*FREQ(J)
      INCH = 19
      NOCH = 4
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      TEMP = INTG
      FREQ(J) = FREQ(J)*TEMP
      IF (INPT(24).EQ.LPHA(48)) GO TO 121
      MBCD(J) = LPHA(44)
      GO TO 101
  121 MBCD(J) = LPHA(48)
      GO TO 101
  130 INCH = 6
      NOCH = 2
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      LRTP = INTG
      INCH = 17
      NOCH = 3
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      RDOS = INTG
      WRITE (6,194)
      WRITE (6,195)
      WRITE (6,193) (INPT(N),N=1,72)
      WRITE (6,195)
      LINE = 58
      GO TO 100
  140 I = I + 1
      INCH = 4
      NOCH = 3
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      MQID(I) = INTG
      INCH = 8
      NOCH = 8
      CALL BCDINT
      IF (IERR.EQ.1) GO TO 180
      QUOT(I) = INTG
      IENT = I
      GO TO 100
  180 IF (INER.EQ.1) GO TO 181
      INER = 1
      WRITE (6,192)
      LINE = LINE -2
  181 WRITE (6,193) (INPT(I),I=1,72)
      LINE = LINE - 2
      IF (LINE.GT.6) GO TO 183
      WRITE (6,194)
      WRITE (6,195)
      WRITE (6,195)
      LINE = 60
  183 IF (MBTK.EQ.1) GO TO 101
      GO TO 100
  200 IJNT = IENT - 1
```

EXTERNAL FORMULA NUMBER - SOURCE STATEMENT

```
      DO 40 IJ = 1, IJNT
      JI = IJ + 1
      IF (MQID(IJ).LE.MQID(JI)) GO TO 40
      KEMP = MQIC(JI)
      TEMP = QUOT(JI)
      MQID(JI) = MQID(IJ)
      QUOT(JI) = QUOT(IJ)
      MQID(IJ) = KEMP
      QUOT(IJ) = TEMP
      IF (IJ.EQ.1) GO TO 40
      IK = IJ
   41 IK = IK - 1
      KI = IK + 1
      IF (IK .EQ. 0) GO TO 40
      IF (MQID(IK) .LE. MQID(KI)) GO TO 40
      KEMP = MQID(IK)
      TEMP = QUOT(IK)
      MQID(IK) = MQID(KI)
      QUOT(IK) = QUOT(KI)
      MQID(KI) = KEMP
      QUCT(KI) = TEMP
      GO TO 41
   40 CONTINUE
      DO 202 J = 1,500
      NOTE(J) = 0
      NODR(J) = 0
      VALU(J) = 0.
      MBNO(J) = 0
  202 CONTINUE
      DO 201 K = 1, 1500
      NUTE(K) = 0
      MQNO(K) = 0
      TECH(K) = 0.
      COST(K) = 0.
      CSPS(K) = 0.
      PSTE(K) = 1.
      DVAL(K) = 0.
  201 CONTINUE
      I = 0
      J = 0
      K = 0
      L = 0
      LMID = 0
      LTID = 0
      MBTK = 1
      GO TO 102
  280 IF (LRCD .NE. 1) GO TO 281
      WRITE (8,1903)
      REWIND 8
      GO TO 505
  506 WRITE (6,1902) (IXTE(N), N=1,120)
  505 READ (8,1902) (IXTE(N), N=1,120)
      IF (IXTE(2) .NE. LPHA(6)) GO TO 506
      REWIND 8
  281 REWIND 9
      STOP
```

```
          EXTERNAL FORMULA NUMBER   -   SOURCE STATEMENT

  300 IF (INER.EQ.1) GO TO 280
      KENT = K
      NUMB = 0
      TCST = 0.
      TVAL = 0.
      DO 2  J = 1, JENT
      NUMB = NOTE(J) + NUMB
      KIND = IXTE(J)
      PFTE = 1.
      DO 1 K = KIND, NUMB
      TCST = COST(K) + TCST
      PSTE(K) = 1. - PSTE(K)
      PFTE = PFTE*PSTE(K)
    1 CONTINUE
      PFTE = 1. - PFTE
      VALU(J) = FREQ(J)*PFTE
      TVAL = VALU(J) + TVAL
    2 CONTINUE
      TEMP = 0.
      DO 6 NOTK = 1, KENT
      NUMB = 0
      DO 3 I = 1,JENT
      NUMB = NOTE(I) + NUMB
      KIND = IXTE(I)
      DO 4 J = KIND, NUMB
      IF (PSTE(J) .EQ.1.) GO TO 4
      PSUB = PSTE(J)
      PSTE(J) = 1.
      PFTE = 1.
      DO 5 K = KIND,NUMB
      PFTE = PFTE * PSTE(K)
    5 CONTINUE
      TVUB = (1. - PFTE) * FREQ(I)
      DVAL(J) = VALU(I) - TVUB
      TECH(J) = DVAL(J) / CSPS(J)
      PSTE(J) = PSUB
    4 CONTINUE
    3 CONTINUE
      VEMP = 1.
      DO 7 L = 1, KENT
      IF (TECH(L) .GE. VEMP) GO TO 7
      VEMP = TECH(L)
      LIND = L
    7 CONTINUE
      L = LIND
      TEMP = TEMP + 1.
      TECH(L) = TEMP
      PSTE(L) = 1.
      DO 8 M = 1, JENT
      IF (L .GE. IXTE(M) + NOTE(M)) GO TO 8
      IF (L .LT. IXTE(M)) GO TO 8
      VALU(M) = VALU(M) - DVAL(L)
      GO TO 6
    8 CONTINUE
    6 CONTINUE
      VEMP = 0.
```

EXTERNAL FORMULA NUMBER - SOURCE STATEMENT

```
      GO TO 400
  310 VEMP = VEMP + 1.
      DO 350 K = 1, KENT
      IF (TECH(K) .NE. VEMP) GO TO 350
      GO TO 355
  350 CONTINUE
      GO TO 280
  355 IDMQ = 0
      DO 352 I = 1,IENT
      IF (MQID(I).NE.MQNO(K)) GO TO 352
      IDMQ = 1
      IF (BUDG(I)-COST(K).LT.QUOT(I)) GO TO 310
      GO TO 351
  352 CONTINUE
      IF (IDMQ .EQ. 0) GO TO 310
  351 DO 353 M = 1, JENT
      IF (K .GE. IXTE(M) + NOTE(M)) GO TO 353
      IF (K .LT. IXTE(M)) GO TO 353
      IF (NOTE(M) -NODR(M).GT.1) GO TO 354
      IF (MBCD(M).EQ.LPHA(44)) GO TO 310
      IF (NOTE(M)-NODR(M).EQ.1) GO TO 354
      GO TO 310
  353 CONTINUE
      GO TO 310
  354 IDMB = MBNO(M)
      IDTE = NUTE(K)
      TCST = TCST - COST(K)
      DELC = COST(K)
      NODR(M) = NODR(M) + 1
      IF (NOTE(M) - NODR(M) .NE. 0) GO TO 356
      MBTK = MBNO(M)
  356 KORD = KORD + 1
      MQNO(K) = MQNO(K) - 1000
      BUDG(I) = BUDG(I) - COST(K)
      COST(K) = 0.
      DELV = DVAL(K)
      TVAL = TVAL - DELV
      GO TO 450
  400 KLIN = JENT/13 + 4
      IF (LINE - KLIN.GE.5) GO TO 409
      WRITE (6,194)
      WRITE (6,195)
      WRITE (6,195)
      LINE = 62
  409 WRITE (6,196)
      LINE = LINE - 2
      WRITE (6,197) (MBCD(J),MBNO(J),J=1,JENT)
      LINE = LINE - (JENT/13)
      KLIN = IENT/8 + 3
      IF (LINE - KLIN.GE.3) GO TO 403
      WRITE (6,194)
      WRITE (6,195)
      WRITE (6,195)
  403 WRITE (6,198)
      WRITE (6,199) (MQID(I),QUOT(I),I=1,IENT)
      LINE = 6
```

```
EXTERNAL FORMULA NUMBER   -   SOURCE STATEMENT

      KORD = 1
      MBTK = 0
  450 IF (LINE.GT.6) GO TO 451
      WRITE (6,194)
      WRITE (6,195)
      WRITE (6,1190)
      WRITE (6,1191)
      WRITE (6,1192)
      LINE = 51
      IF (KORD.GT.1) GO TO 451
      WRITE (6,1193) TVAL, TCST
      GO TO 470
  451 WRITE (6,1194) KORD,IDMB,IDTE,TVAL,DELV,TCST,DELC,MBTK
      MBTK = 0
  470 IF (LRCD.NE.1) GO TO 310
      IF (KORD.GT.1) GO TO 471
      WRITE (8,1900) LRTP
      WRITE (8,195)
  471 DO 477 L = 1, LENT
      IF (KORD .EQ. IOUT(L)) GO TO 478
  477 CONTINUE
      GO TO 310
  478 WRITE (8,1901) KORD
      DO 60 L = 1,KENT
      PSTE(L) = 0.
   60 CONTINUE
      II = ((IENT-1)/10) + 1
      M = -9
      N = 0
      DO 90 I = 1, II
      M = M + 10
      N = N + 10
      IF (N.LE.IENT) GO TO 91
      N = IENT
   91 WRITE (8,1195) (MQID(MM),MM = M,N)
      WRITE (8,1196) (QUOT(MM),MM = M,N)
      WRITE (8,1197)
      WRITE (8,1198)
      WRITE (8,1197)
      DO 472 LL = 1,10
      KBUF(LL) = 0
      MBUF(LL) = 0
      CBUF(LL) =0.
      CMQT(LL) =0.
  472 CONTINUE
   92 MQGO = 0
      DO 80 L = 1,KENT
      IF (MQNO(L).LT.MQID(M)) GO TO 80
      IF (MQNO(L).GT.MQID(N)) GO TO 80
      IF (PSTE(L) .EQ. -1.) GO TO 80
      MQGO = 1
      DO 70 K = M,N
      IF (MQID(K).NE.MQNO(L)) GO TO 70
      J = K
   88 IF (J.LT.11) GO TO 87
      J = J - 10
```

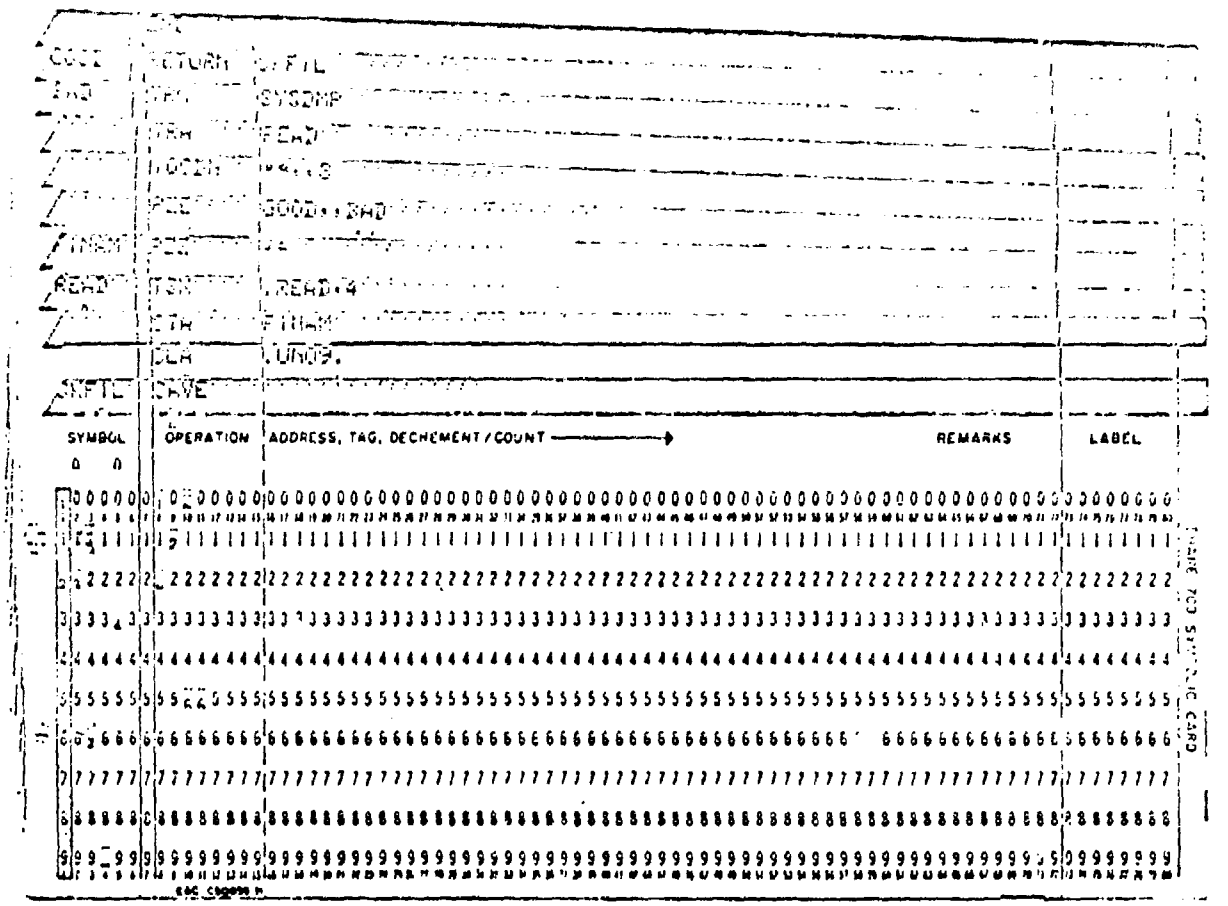
```
      EXTERNAL FORMULA NUMBER   -   SOURCE STATEMENT

      GO TO 80
   87 IF (CBUF(J).NE.0.) GO TO 80
      CBUF(J) = COST(L)
      CMQT(J) = CMQT(J) + COST(L)
      KBUF(J) = NUTE(L)
      DO 50 JJ = 1,JENT
      IF (L .GE. IXTE(JJ) + NOTE(JJ)) GO TO 50
      IF (L .LT. IXTE(JJ)) GO TO 50
      MBUF(J) = MBNO(JJ)
      PSTE(L) = -1.
      GO TO 80
   50 CONTINUE
   70 CONTINUE
   80 CONTINUE
      DO 474 LL = 1,10
      IF (MBUF(LL) .NE. 0) GO TO 475
  474 CONTINUE
      GO TO 476
  475 WRITE (8,1199) (MBUF(LL),KBUF(LL),LL = 1,10)
      WRITE (8,1196) (CBUF(LL),LL = 1,10)
      DO 473 LL = 1,10
      KBUF(LL) = 0
      MBUF(LL) = 0
      CBUF(LL) =0.
  473 CONTINUE
      IF (MQGO.NE.0) GO TO 92
  476 WRITE (8,1197)
      WRITE (8,1200)
      WRITE (8,1196) (CMQT(LL),LL = 1,10)
      WRITE (8,1197)
      WRITE (8,195)
   90 CONTINUE
      WRITE (8,1201) KORD
      WRITE (8,194)
      GO TO 310
  500 REWIND 8
      DO 508 J =1, 16
      IOUT(J) =0
  508 CONTINUE
      LRCD = 1
      LENT = 0
      INCH = 7
      NOCH = 0
      KEMP = 0
      DO 507 J = 1, 16
  501 IF (KEMP.GT.1) GO TO 100
      INCH = INCH + NOCH + KEMP
      NOCH = 0
      KEMP = 0
      DO 503 N = INCH,72
      IF (INPT(N).EQ.LPHA(48)) GO TO 502
      IF (KEMP.EQ.1) GO TO 504
      NOCH = NOCH + 1
      GO TO 503
  502 KEMP = KEMP + 1
      IF (KEMP.GT.1) GO TO 504
```

```
                EXTERNAL FORMULA NUMBER  -  SOURCE STATEMENT

      503 CONTINUE
          IF (NOCH.EQ.0) GO TO 100
      504 CALL BCDINT
          IF (IERR.EQ.1) GO TO 180
          IOUT(J) = INTG
          LENT = J
      507 CONTINUE
          GO TO 100
      100 FORMAT (48A1)
      191 FORMAT (72A1)
      192 FORMAT (1H0, 97HTHE FOLLOWING CARD(S) CONTAIN(S) ERROR(S) THAT MUS
         2T BE CORRECTED BEFORE COMPUTATIONS CAN BE MADE.)
      193 FORMAT (1H0,72A1)
      194 FORMAT (1H1,119X)
      195 FORMAT (1H0,119X)
      196 FORMAT (109H  FOLLOWING IS A LIST OF MBPA(S) FOR THIS RUN OF THIS
         2PROGRAM. THOSE PRECEDED BY ASTERISKS CANNOT BE DROPPED.)
      197 FORMAT (13(3H  (,1A1,1H),I4))
      198 FORMAT (76H  FOLLOWING IS A LIST OF MONETARY QUOTAS WITH THE NUMBE
         2R OF DOLLARS IN EACH.)
      199 FORMAT (8(I3,2H $,F9.0,1H*))
     1190 FORMAT (103H0 COORDINATE  *  TASK ELIMINATED   *   TECHNICAL VALUE
         2   *              COST              *  MBPA ELIMINATED)
     1191 FORMAT (97H     NUMBER     *     MBPA    TASK      *      TOTAL    DELTA
         2  *      TOTAL         DELTA     *       MBPA)
     1192 FORMAT (120X)
     1193 FORMAT (37H         1           NONE    NONE        ,F9.3,15H     NONE
         2     $,F11.0,25H    $  NONE              NONE)
     1194 FORMAT (5X,I4,10X,I4,4X,I3,7X,F9.3,2X,F7.3,6X,F11.0,2X,F9.0,9X,I4)
     1195 FORMAT (1H ,9(5H  MQ ,I3,4X),5H  MQ ,I3,3X)
     1196 FORMAT (1H ,9(1H$,F9.0,2X),1H$,F9.0,1X)
     1197 FORMAT (10(12H   ******   ))
     1198 FORMAT (12H0 MBPA TASK ,9(12H  MBPA TASK ))
     1199 FORMAT (10(2X,I4,1X,I3,2X))
     1200 FORMAT (10(3X,5HTOTAL,4X))
     1201 FORMAT (19H0 END OF COORDINATE,I4,97X)
     1900 FORMAT (10H0  LRTP   ,I2,108X)
     1901 FORMAT (30H0CONFIGURATION OF COORDINATE  ,I4,86X)
     1902 FORMAT (120A1)
     1903 FORMAT (6H FINIS,114X)
          END
```

```
EXTERNAL FORMULA NUMBER  -  SOURCE STATEMENT  -
      SUBROUTINE BCDINT
      COMMON LPHA(48),INPT(072),INCH,NOCH,INTG,IERR,INTI
      COMMON IXTE(500),IPTI,IPCH,NPCH,IPTG,IPRR
      INTI = 0
      INTG = 0
      IERR = 0
      IF (NOCH.EQ.0) GO TO 5
      DO 1  J=1,NOCH
      K = J+ INCH - 1
      DO 2 I = 1,10
      L = I + 26
      IF (INPT(K).EQ.LPHA(L)) GO TO 3
    2 CONTINUE
      IF (INPT(K).EQ.LPHA(48)) GO TO 4
    5 IERR = 1
    6 RETURN
    4 IF (INTG.NE.0) GO TO 5
      GO TO 7
    3 INTG = INTG * 10 + I - 1
      INTI = 1
    1 CONTINUE
      RETURN
    7 IF (INTI.EQ.0) GO TO 1
      GO TO 5
      END
```



SUBROUTINE SKFIL (SKIP END-OF-FILE MARK)

3.5 Debugging Log

In the course of getting a computer program to operate correctly, one attempts to follow a process which will achieve one's objective most quickly and most economically. Computer operating systems contain routines to aid in this checkout process. The IBSYS system provides the PDUMP routine, and this was the means used to verify the correctness of the program's operations.

The "Debugging" went as follows:

(a) Check out card reading processes -- Use as input the cards described in Sections 3.1.1.2, 3.1.1.3 and 3.1.1.4. Verify their correct reading by PDUMP of Tables BUDG, MQID, QUOT, FREQ, MBNO, MBCD, IXTE, NOTE, NUTE, PSTE, COST, CSPS, MQNO, IOUT and LPHA.

(b) Check out error routine -- Introduce cards with erroneous data in each field. Examine Item INER (input error indicator) as well as output messages which specified the card(s) in error.

(c) Check out computations -- Using input data that had been checked in the course of (a) above, record, via PDUMP. Tables PSTE, TECH, VALU and DVAL as the computations are being made. Check enough cases to ascertain the correctness of the results.

(d) Check output -- With data from (c) as criteria, verify that same information that is in tables is printed. Examine outputs themselves for correctness of format.

Upon completion of these tests, the program was operated to produce the information described in Section 4., entitled, "Numerical Examples of Model Outputs".

4. NUMERICAL EXAMPLES

The purpose of this section is to illustrate computer program outputs for several sets of input constraints by making use of hypothetical data. The volume of data, estimated by personnel at Headquarters, AMC, is believed to be representative of the amount of data that may be encountered in actual operation. No further significance should be attached to the hypothetical data, or computer outputs, presented herein.

4.1 Generation of Hypothetical Data

4.1.1 Generation of MBPA-TK-WE Structure

The generation of the hypothetical input data was based on the assumption that Headquarters, AMC, received descriptions of 55 Research Development Objectives (RDO's); the number 55 was chosen because there are 55 RDO's in the 1 October 1964 issue of the Research and Development Long Range Plan (RDLRP). It was further assumed that the 55 RDO's resulted in the identification of 150 Major Barrier Problem Areas (MBPA's).

The number of Tasks associated with each MBPA was assumed to be uniformly distributed between 1 and 4 with a mean of 2.5. The distribution was sampled to determine the number of Tasks (TK's) associated with each MBPA. This sampling resulted in a total of 388 TK's.

4.1.2 MBPA Parameters

The number of RDO's that each MBPA is associated with was derived by sampling a Poission distribution with a mean of 10.

Given that an MBPA was associated with an RDO, a uniform distribution between 1 and 5 with mean of 3 was sampled to determine the frequency of appearance of an MBPA within an RDO. Furthermore, it was assumed that the number of Technical Approaches associated with an RDO was equal to the sum of the frequencies of appearance of MBPA's within RDO's. The above generated values (frequencies and number of Technical Approaches) were then utilized to determine the expected probability that each MBPA will be encountered in a Technical Approach.

4.1.3 Annual Work Effort Parameters

The costs of the Annual Work Efforts (WE's) were assumed to be uniformly distributed between $30,000 and $50,000 with mean of $40,000. The cost of each WE was determined by sampling this distribution.

The probability of success of each WE was determined by assigning one of six values (.05, .20, .40, .50, .80, .95). These values were assumed to be binomially distributed with a mean .5.

After determining the cost and probability of success of each WE, the WE's associated with each Task were sequenced in order of increasing value of cost/1-Probability of Success.

Furthermore, it was also assumed that a total of 10 Field Establishments (Monetary Quotas) proposed the Tasks and the assignments of Tasks were assumed to be randomly distributed among the Field Establishments.

4.2 Computer Runs

Using the hypothetical MBPA and WE parameters previously discussed seven computer runs were made varying the MBPA and Monetary Quota (MQ) cost constraints from run to run. These runs were made utilizing the IBM 7090 computer at the U.S. Army Strategy Tactics and Analysis Group, Bethesda, Maryland. The print out of one of the runs is given in Appendix II.

The outputs of the seven runs are given in Figures 4-1 and 4-2. All of the Configurations produced by each run have not been plotted because of the limited size of each figure, but a sufficient number points are given to clearly portray the shape and characteristics of the curves.

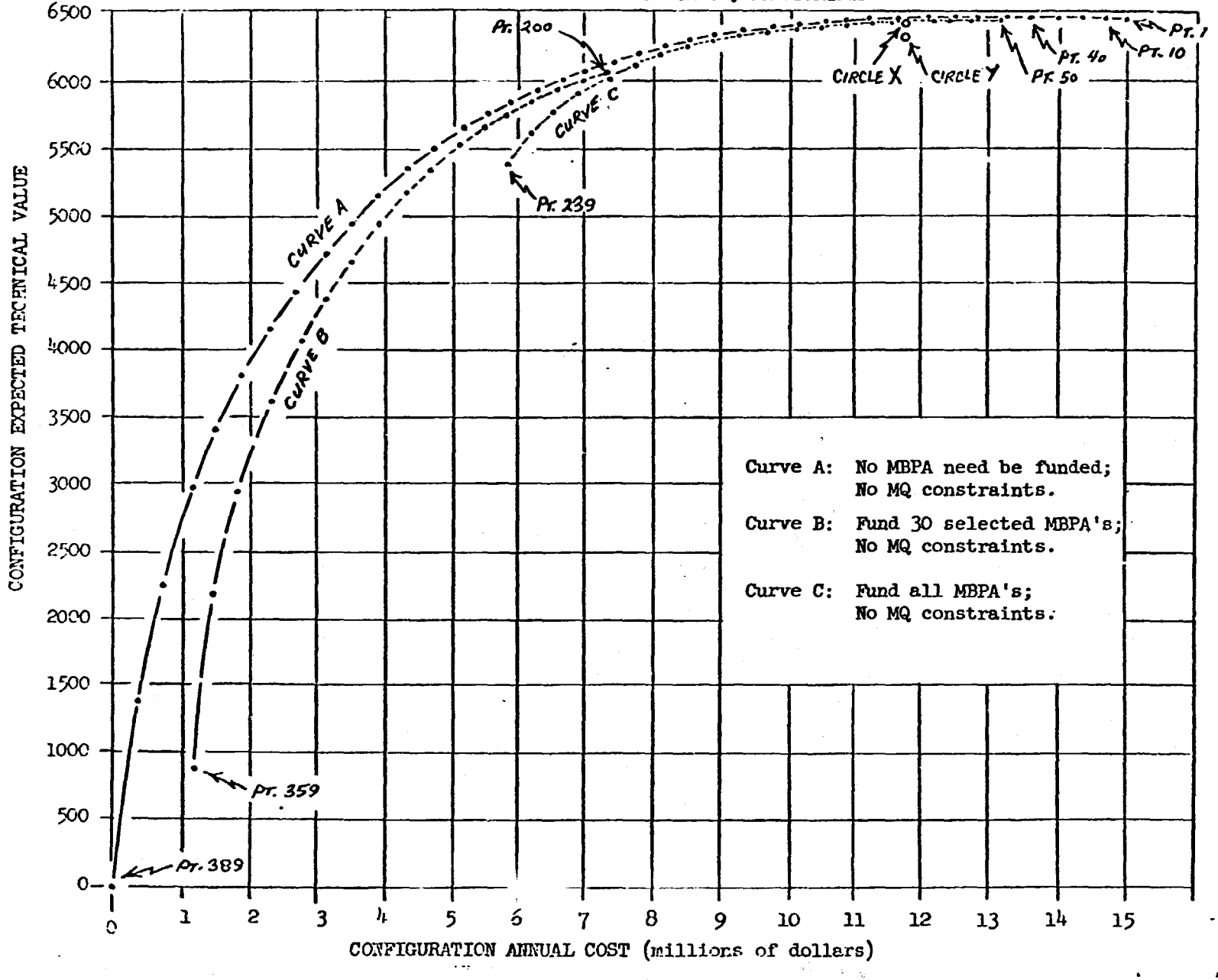
4.2.1 Outputs Varying MBPA Work Effort Constraints

The curves in Figure 4-1 illustrate the effect of varying the MBPA constraints without any MQ constraints (zero funds for each MQ).

Curve A depicts the Configurations of maximum expected technical value in which no MBPA need be funded. Since the 150 MBPA's comprise 388 TK's, the total number of possible Configurations (or points on the curve) is 389. Appendix II contains a complete listing of all these Configurations. Of this number, 389, the first (the Configuration consisting of 388 TK's), the last (the Configuration consisting of 0 TK's), and every tenth one were plotted. For Curve A (as well as the other curves), the cost intervals between points (i.e., the change along the abscissa) is quite uniform. This is a consequence of the fact that the cost of a WE was postulated in the relatively narrow range of $30,000 - $50,000. Thus, the cost interval between any pair of plotted points is around $400,000 (10 x $40,000). The expected technical value intervals between points (i.e., the change along the ordinate), however, increases as one progresses along the curve from right to left as expected.

Figure 4-1

CONFIGURATIONS OF MAXIMUM EXPECTED TECHNICAL VALUE UNDER VARIOUS MBPA CONSTRAINTS AND NO MQ CONSTRAINTS



Curve C depicts the Configurations of maximum expected technical value in which all MBPA's must be funded. Since there are 150 MBPA's, the total number of possible Configurations is 239 (388-150+1) and ranges from the Configuration consisting of 388 TK's to one of 150 TK's (i.e., one for each MBPA). The curve stops at point 239 since none of the remaining TK's can be eliminated without violating the requirement that every MBPA must be funded. The last point and every tenth one commencing with No. 50 are plotted. Incidentally, the first 40 points on Curve C are identical with those of Curve A.

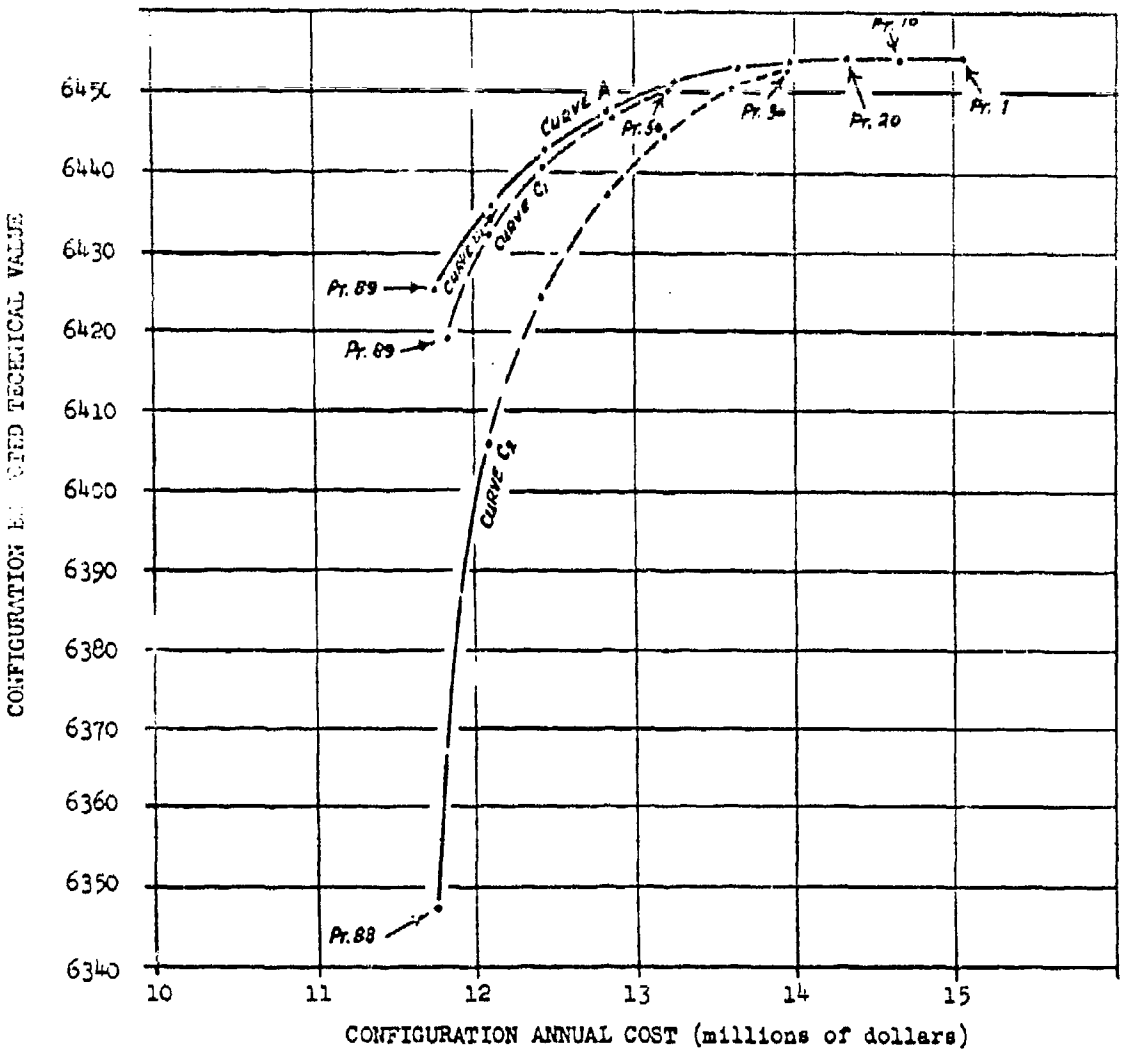
Curve B depicts Configurations of maximum expected technical value in which 30 MBPA's (randomly selected) were required to be funded. The total number of such Configurations is 359, of which the last one and every tenth one commencing with No. 200 are plotted. The points to the right of No. 200 are not plotted since they fall between Curves A and B roughly between the plotted points.

4.2.2 Outputs Varying MBPA Work Efforts and MQ Cost Constraints

In Figure 4-2, Curves A_1, B_1, C_1 correspond to Curves A, B, C of Figure 4-1 insofar as MBPA constraints are concerned; however, a common set of MQ constraints, as defined below, were applied. Normally, Curves A_1, B_1, C_1, would have been included on Figure 4-1; however, they fall so closely to the curves already plotted on Figure 4-1 that Curves A_1, B_1, C_1 would all start with Point No. 1 and end within circle X. Thus they were plotted separately in Figure 4-2 on an enlarged scale. Curve C_2 can be associated with Curve C_1 as discussed below.

Figure 4.2

CONFIGURATIONS OF MAXIMUM EXPECTED TECHNICAL VALUE
UNDER VARIOUS MBPA CONSTRAINTS AND MQ CONSTRAINTS



Curve A_1: No MBPA need be funded; MQ constraints as defined in 4.2.2

Curve B_1: Fund 30 selected MBPA's; MQ constraints as defined in 4.2.2

Curve C_1: Fund all MBPA's; MQ constraints as defined in 4.2.2

Curve C_2: Fund all MBPA's; MQ constraints as defined in 4.2.2

Curve A_1 depicts Configurations of maximum expected technical value in which no MBPA need be funded and with MQ constraints that represent 75% of the number of the 1st fiscal year WE's chargeable to each MQ times the average cost of each WE ($40,000). The number of possible Configurations is 89. None of the remaining TK's of the last Configuration can be eliminated since a violation of one of the MQ constraints would then occur. The first, last and every tenth Configuration are plotted.

The most significant feature to be noticed upon comparing curves A and A_1 is that Curve A_1, throughout its length, corresponds very closely to Curve A. In fact, the first 49 Configurations are identical. While not exactly true, it can be stated that the result of imposing the stated MQ constraints upon Curve A is a shortening of Curve A (and thus a reduction in the number of possible Configurations). This ensues because of the relatively narrow and comparatively uniform WE cost figures, i.e., $30 - $50,000. For example, commencing with the Configuration consisting of all TK's, each TK is considered for elimination in the same order as that for Curve A. The procedure is to eliminate it if a MBPA constraint or an MQ constraint is not violated. In this case, there are no MBPA constraints so the only consideration is the individual MQ constraints. Since each MQ represents an amount of money that is large in comparison to an individual WE cost and all WE costs are quite uniform, then a considerable number of the TK's to be considered for elimination will be eliminated in their original order. It is re-emphasized that in determining the original order of TK's to be considered for elimination that expected costs were utilized in the calculations; however, once this order is established and MQ constraints are considered only the first fiscal year TK (i.e., WE) cost is involved.

Curve C_1 depicts Configurations of maximum expected technical value in which all MBPA's must be funded and with the same MQ constraints as for Curve A_1. There are a total of 89 possible Configurations. The last and every tenth one, commencing with No. 50, are plotted. The curve stops at point 89 since elimination of any of the remaining TK's would violate either an MBPA or an MQ constraint. The first 40 Configurations are identical to the first 40 of Curve A_1; the number of such occurrences being less in this case than the number (49) in the case of Curves A and A_1 as might be expected because of the inclusion of the MBPA constraints. The discussion in 4.3.3.1 regarding curve length also applies to curve C_1.

Curve B_1 depicts Configurations of maximum expected military value in which 30 randomly selected MBPA's must be funded and which meet the same MQ constraints as does Curve A_1. It consists of 89 possible Configurations; the first 40 of which are identical to those of Curve A_1. The remaining points have not been plotted since they fall between Curves A_1 and C_1; merely the position of the curve has been labeled. The discussion in 4.3.3.1 is also applicable herein.

Curve C_2 depicts Configurations of maximum expected technical value in which every MBPA must be funded and which meet MQ constraints defined as follows. The overall amount available in all MQ's was established as $11,640,000; the same as that for the total of MQ's for curve C_1. However, the distribution of moneys between MQ's was randomly made and varied from about 50% to 95% of the number of 1st fiscal year WE's chargeable to each MQ times the average cost of each WE ($40,000) instead of a constant 75% for all MQ's as done for curve C_1. Expressed in another fashion, the distribution of moneys for the curve C_1 MQ's was such that each AMC R&D Field Establishment was assumed

to have proposed a lot of TK's so that the costs chargeable to the appropriate MQ exceeded the minimum in it by 100% whereas another AMC R&D Field Establishment may have proposed only a few TK's so that the costs chargeable to the appropriate MQ barely exceeded the minimum available in that MQ.

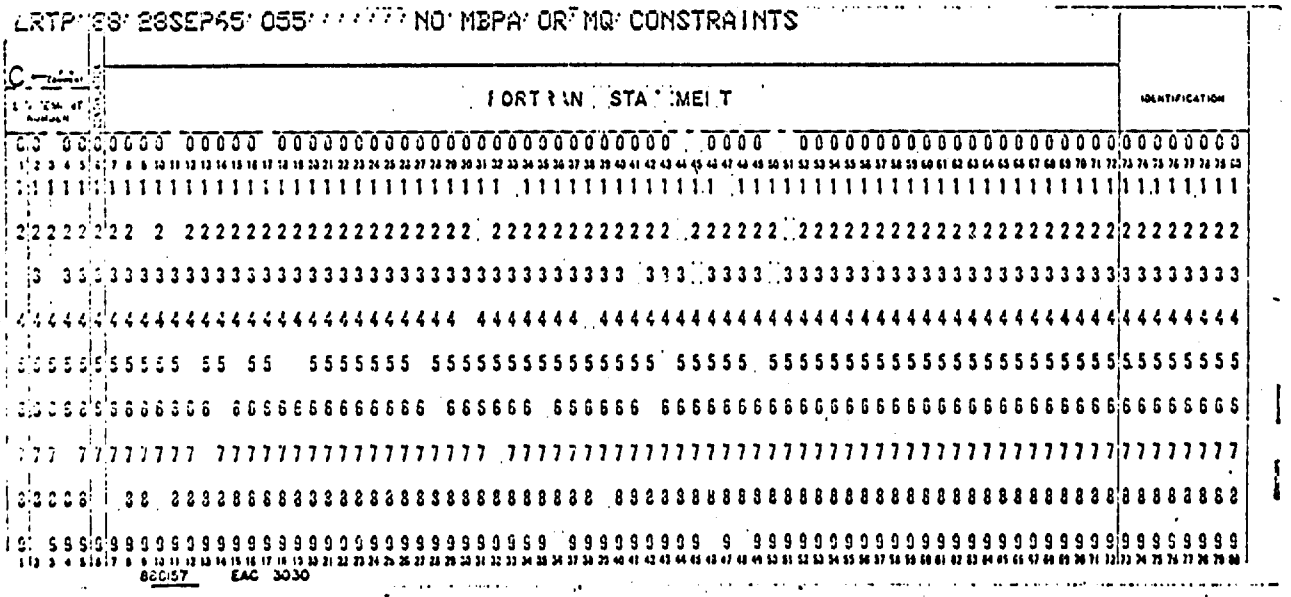
This curve consists of 88 possible Configurations of which every tenth one commencing with No. 30 and the last one are plotted. The last point of this curve falls approximately within the Circle Y indicated in Figure 4-1. No Configuration other than the first is identical to any on curve A_1. As expected, the shape of this curve departs considerably from those of curves A_1, B_1, C_1; curve C_2 dropping in expected technical value more rapidly as cost decreases. This results from the fact that the minimum amounts in some MQ's are close to the sums of the costs of all this chargeable to those MQ's; thus few TK's can be dropped which means less desirable TK's may be required to be maintained while more desirable TK's chargeable to other MQ's are eliminated.

APPENDIX I

INPUT CARD DESCRIPTION

APPENDIX I - INPUT CARD DESCRIPTION

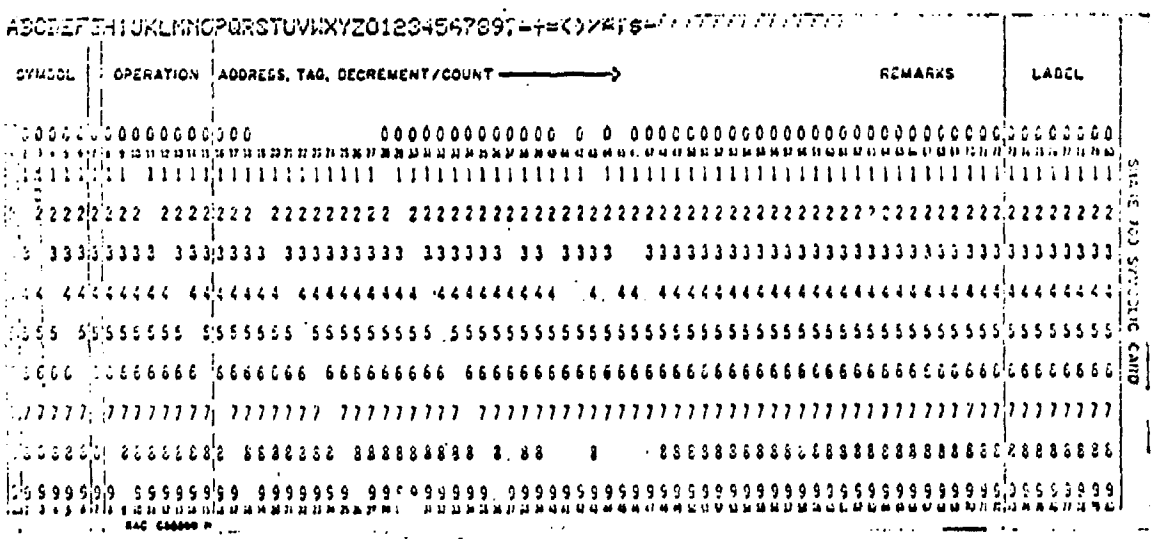
FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-4	Letters	Identification of Card
2	6-7	Digits	ID of Program Run
3	9-15	L/D	Date
4	17-19	D	Count of RDOs
5	21-72	Letters Digits Special	Comments



"LRTP" CARD

APPENDIX I - INPUT CARD DESCRIPTION

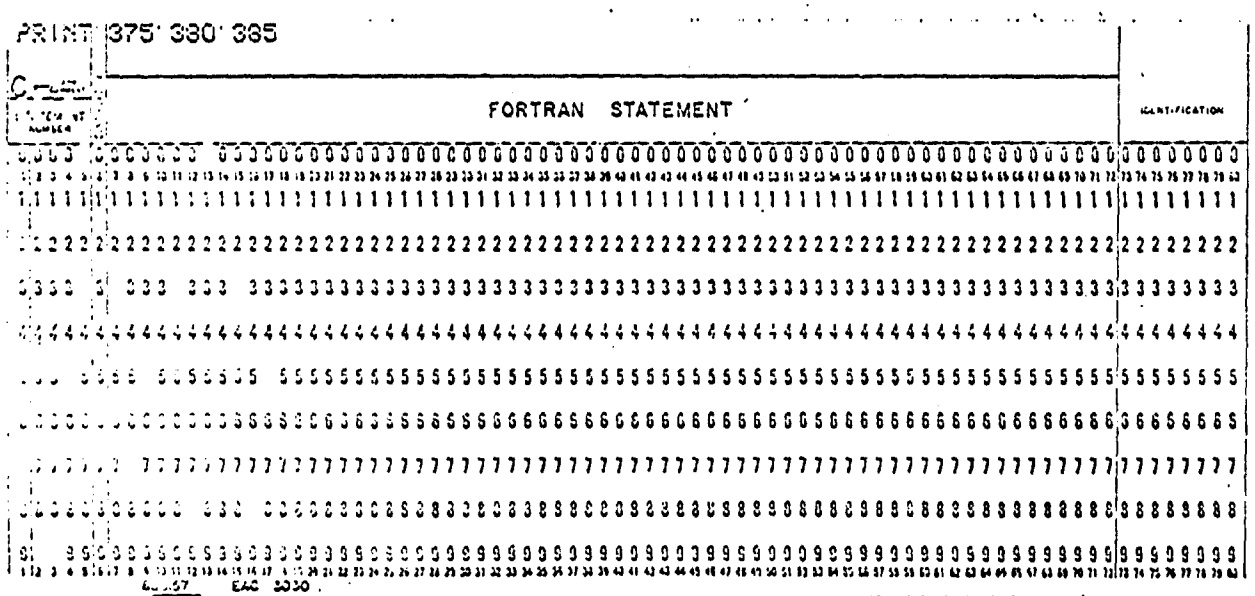
FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-26	Letters	The Alphabet
2	27-36	Digits	Modulo 10
3	37-48	Special	Other Characters
	49-72		Not Used



"BCD IMAGE" CARD

APPENDIX I - INPUT CARD DESCRIPTION

FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-5	Letters	Card ID
2	7-72	Digits Blanks	1 - 16 Numbers, with a Blank between Numbers

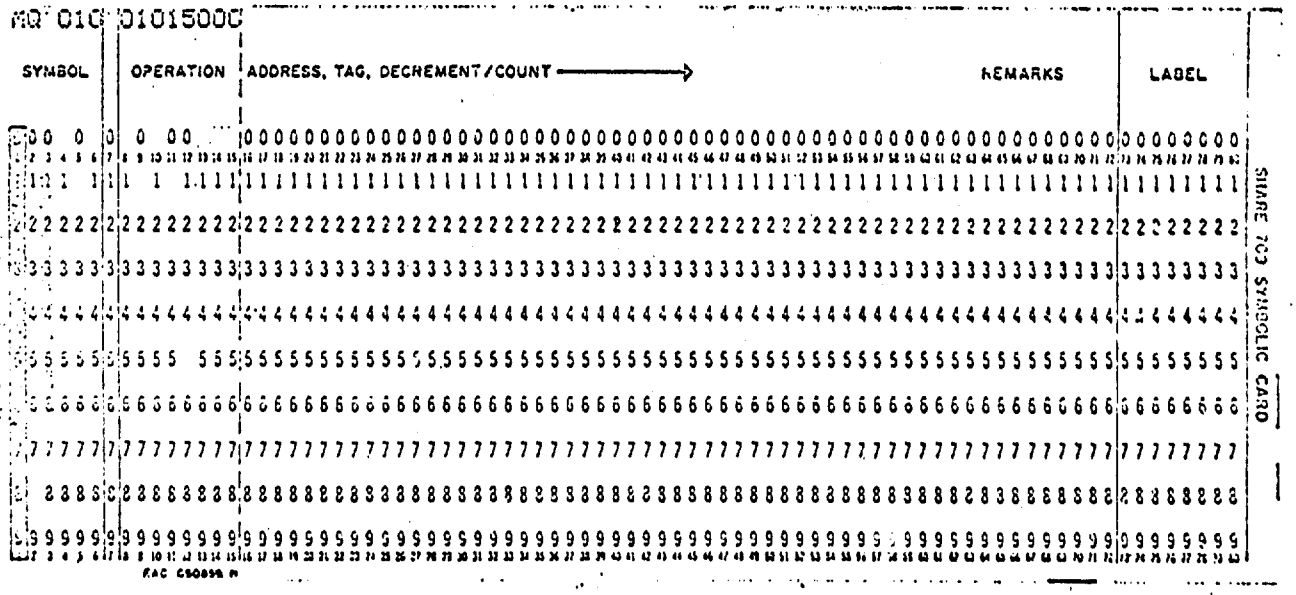


"PRINT" CARD

Best Available Copy

APPENDIX I - INPUT CARD DESCRIPTION

FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-2	Letters	Card ID
2	4-6	Digits	MQ ID
3	8-15	Digits	Number of Dollars



"MQ" CARD

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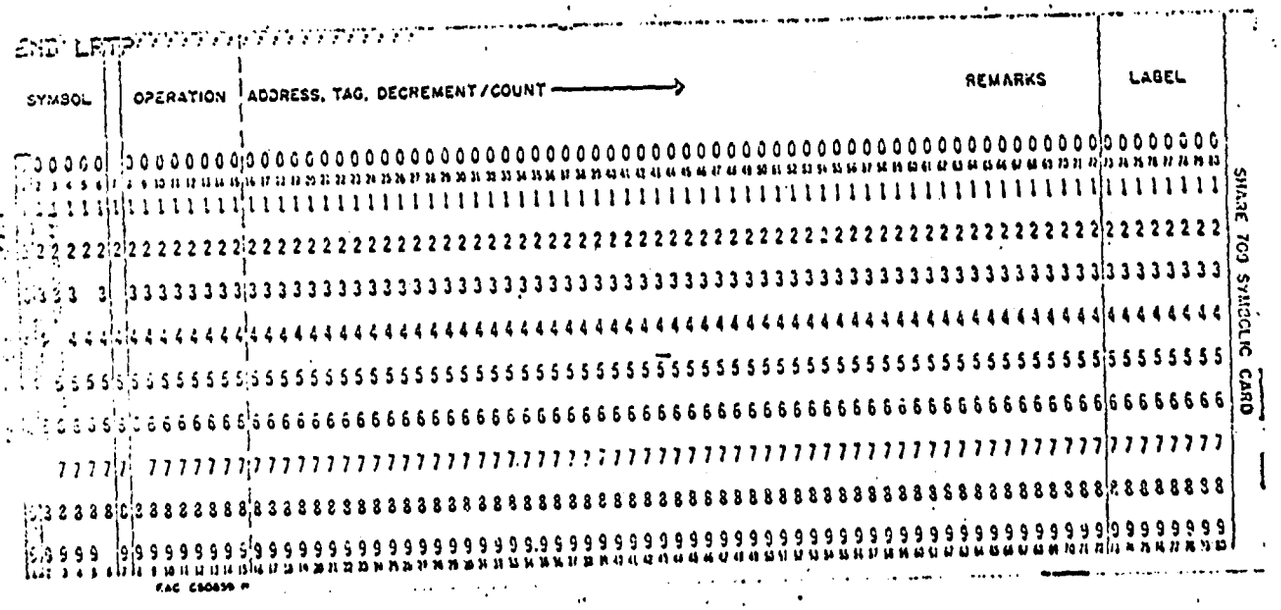
APPENDIX I - INPUT CARD DESCRIPTION

FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-3	Letters	Card ID
2	5-72	L/D/S	Any Comment

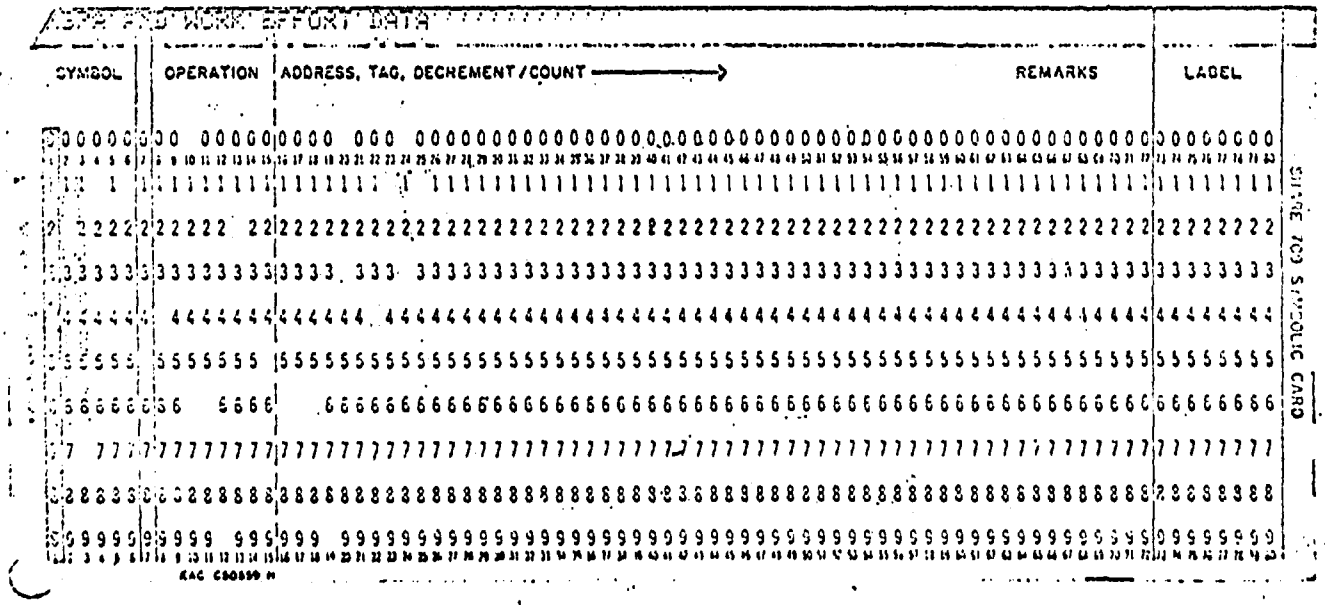


"END" CARD

Best Available Copy

APPENDIX I - INPUT CARD DESCRIPTION

FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-72	L/D/S	Any Comment

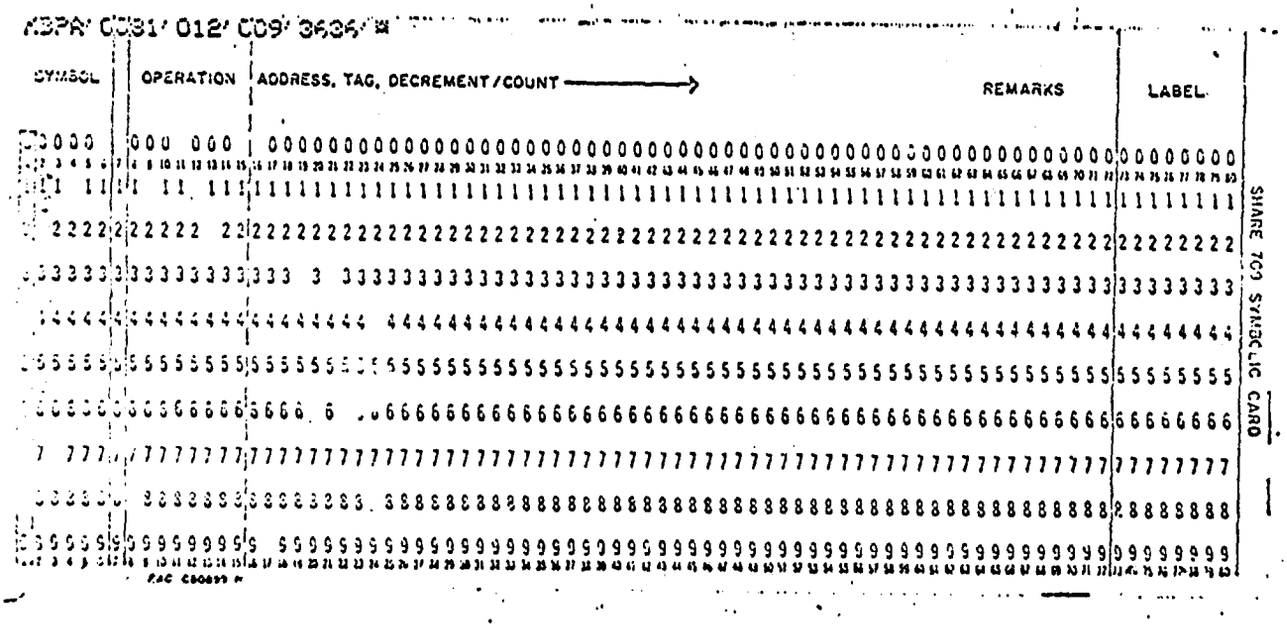


"HEADER" CARD

Best Available Copy

APPENDIX I - INPUT CARD DESCRIPTION

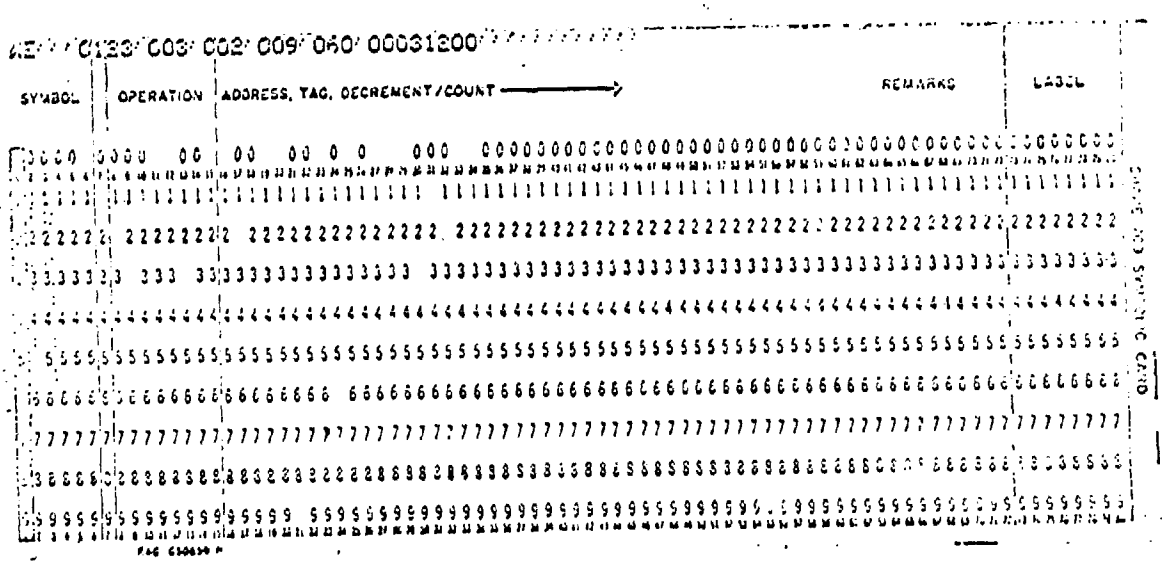
FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-4	Letters	ID of Card
2	6-9	Digits	MBPA ID
3	11-13	Digits	Frequency of Appearance within the RDO (A Percent) (w_k)
4	15-17	Digits	Frequency of Appearance between RDOs (A Count) (l_k)
5	19-22	Digits	RDO Factor (U_k)
6	24	Blank/Any Character	Drop Indicator, where: Blank = may be Eliminated, Other = Do Not Eliminate



"MBPA" CARD

APPENDIX I - INPUT CARD DESCRIPTION

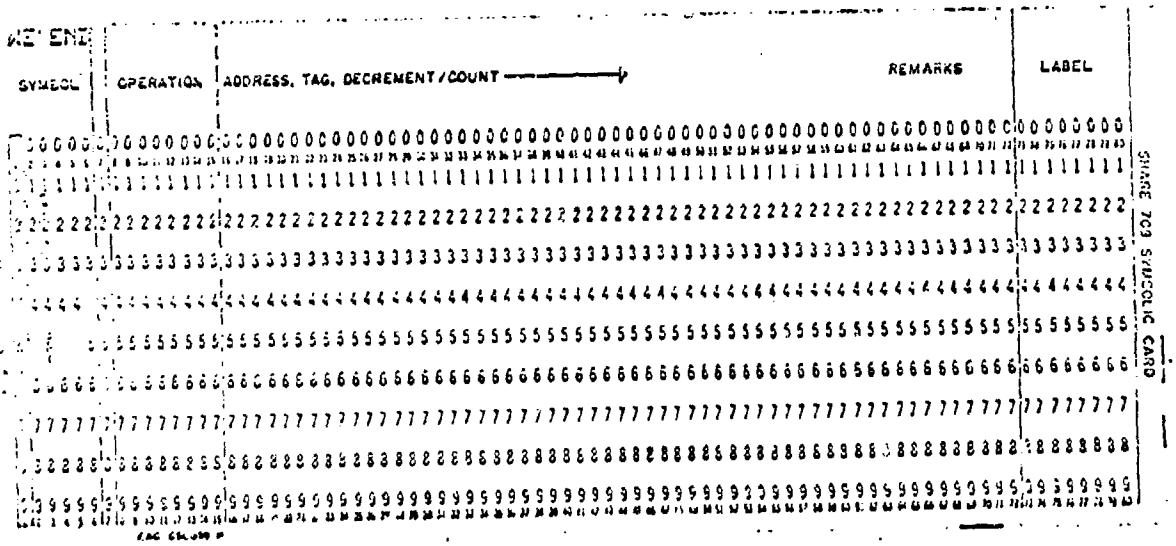
FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-2	Letters	Card ID
2	6-9	Digits	MBPA ID
3	11-13	Digits	Task ID
4	15-17	Digits	WE ID
5	19-21	Digits	MQ ID
6	23-25	Digits	Probability of Success (A Percent)
7	27-34	Digits	Cost (Number of Dollars)



"WE" CARD

APPENDIX I - INPUT CARD DESCRIPTION

FIELD	COLUMNS	CONTENTS	DESCRIPTION
1	1-2	Letters	ID of Card
2	4-6	Letters	Program Control Field (Must be "End")



"WE END" CARD

APPENDIX II

SAMPLE COMPUTER OUTPUT

APPENDIX II

SAMPLE COMPUTER OUTPUT

LRTP 88 28SEP65 055 NO MBPA OR MQ CONSTRAINTS

FOLLOWING IS A LIST OF MBPA(S) FOR THIS RUN OF THIS PROGRAM. THOSE PRECEDED BY ASTERISKS CANNOT BE DROPPED.

( )	1	( )	2	( )	3	( )	4	( )	5	( )	6	( )	7	( )	8	( )	9	( )	10	( )	11	( )	12	( )	13
( )	14	( )	15	( )	16	( )	17	( )	18	( )	19	( )	20	( )	21	( )	22	( )	23	( )	24	( )	25	( )	26
( )	27	( )	28	( )	29	( )	30	( )	31	( )	32	( )	33	( )	34	( )	35	( )	36	( )	37	( )	38	( )	39
( )	40	( )	41	( )	42	( )	43	( )	44	( )	45	( )	46	( )	47	( )	48	( )	49	( )	50	( )	51	( )	52
( )	53	( )	4	( )	55	( )	56	( )	57	( )	58	( )	59	( )	60	( )	61	( )	62	( )	63	( )	64	( )	65
( )	66	( )	67	( )	68	( )	69	( )	70	( )	71	( )	72	( )	73	( )	74	( )	75	( )	76	( )	77	( )	78
( )	79	( )	80	( )	81	( )	82	( )	83	( )	84	( )	85	( )	86	( )	87	( )	88	( )	89	( )	90	( )	91
( )	92	( )	93	( )	94	( )	95	( )	96	( )	97	( )	98	( )	99	( )	100	( )	101	( )	102	( )	103	( )	104
( )	105	( )	106	( )	107	( )	108	( )	109	( )	110	( )	111	( )	112	( )	113	( )	114	( )	115	( )	116	( )	117
( )	118	( )	119	( )	120	( )	121	( )	122	( )	123	( )	124	( )	125	( )	126	( )	127	( )	128	( )	129	( )	130
( )	131	( )	132	( )	133	( )	134	( )	135	( )	136	( )	137	( )	138	( )	139	( )	140	( )	141	( )	142	( )	143
( )	144	( )	145	( )	146	( )	147	( )	148	( )	149	( )	150	(											

FOLLOWING IS A LIST OF MONETARY QUOTAS WITH THE NUMBER OF DOLLARS IN EACH.

0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•
0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•	0	$	0.•
0	$	0.•	0	$	0.•	0	$	0.•	1	$	0.•	2	$	0.•	3	$	0.•	4	$	0.•	5	$	0.•	6	$	0.•
7	$	0.•	8	$	0.•	9	$	0.•	10	$	0.•															

COORDINATE NUMBER	TASK ELIMINATED NSPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	NSPA ELIMINATED NSPA
1	NONE	NONE	6454.537	NONE	$ 15016950.	$ NONE	NONE
2	24	2	6454.533	0.004	14984950.	32000.	0
3	56	1	6454.528	0.006	14946600.	38350.	0
4	24	4	6454.525	0.003	14914950.	31650.	0
5	138	4	6454.515	0.010	14880750.	34200.	0
6	50	4	6454.507	0.008	14837650.	43100.	0
7	59	2	6454.500	0.008	14807650.	30000.	0
8	120	3	6454.488	0.011	14767000.	40650.	0
9	50	3	6454.470	0.019	14728350.	38650.	0
10	30	4	6454.454	0.016	14696100.	32250.	0
11	140	2	6454.435	0.019	14662200.	33900.	0
12	64	1	6454.417	0.018	14629850.	32350.	0
13	40	2	6454.401	0.016	14597200.	32650.	0
14	7	4	6454.378	0.023	14557900.	39300.	0
15	54	2	6454.357	0.022	14521350.	36550.	0
16	121	3	6454.325	0.031	14483150.	38200.	0
17	92	1	6454.286	0.039	14445850.	37300.	0
18	33	2	6454.252	0.034	14409550.	36300.	0
19	27	1	6454.213	0.040	14378700.	30850.	0
20	139	3	6454.178	0.035	14347700.	31000.	0
21	51	2	6454.151	0.027	14314950.	32750.	0
22	74	2	6454.109	0.042	14284150.	30800.	0
23	2	2	6454.071	0.038	14248700.	35450.	0
24	138	1	6454.025	0.045	14214400.	34300.	0
25	49	2	6453.981	0.044	14182200.	32200.	0
26	34	3	6453.916	0.065	14146600.	35600.	0
27	142	1	6453.857	0.059	14107150.	39450.	0
28	2	3	6453.799	0.058	14076150.	31000.	0
29	34	1	6453.697	0.102	14029300.	46850.	0
30	44	2	6453.621	0.076	13986000.	43300.	0
31	40	3	6453.552	0.069	13944350.	41650.	0
32	117	2	6453.492	0.061	13905200.	39150.	0
33	1	1	6453.435	0.057	13874550.	30650.	0
34	3	2	6453.345	0.089	13842750.	31800.	0
35	23	1	6453.292	0.054	13804050.	38700.	0
36	44	4	6453.196	0.095	13768550.	35500.	0
37	51	1	6453.109	0.087	13735950.	32600.	0
38	143	4	6452.992	0.117	13697550.	38400.	0
39	88	4	6452.868	0.124	13663350.	34200.	0
40	85	3	6452.640	0.228	13624650.	38700.	0

COORDINATE NUMBER	TASK ELIMINATED MOPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	MOPA ELIMINATE MOPA
41	57	1	6452.496	0.145	13581550.	43100.	57
42	71	3	6452.340	0.155	13546800.	34750.	0
43	108	2	6452.208	0.132	13511550.	35250.	0
44	69	4	6451.977	0.231	13470000.	41550.	0
45	56	2	6451.790	0.187	13437400.	32600.	0
46	25	3	6451.595	0.195	13387550.	49850.	0
47	11	1	6451.475	0.120	13355850.	31700.	11
48	46	3	6451.275	0.200	13322950.	32900.	0
49	135	1	6451.121	0.154	13288250.	34700.	135
50	124	3	6450.901	0.219	13249650.	38600.	0
51	142	3	6450.662	0.239	13213900.	35750.	0
52	28	1	6450.500	0.162	13172000.	41900.	28
53	10	2	6450.199	0.301	13125850.	46150.	0
54	120	2	6449.989	0.210	13077050.	48800.	0
55	134	3	6449.793	0.196	13031500.	45550.	0
56	130	2	6449.341	0.452	12982650.	48850.	0
57	80	2	6449.123	0.218	12937250.	45400.	0
58	71	1	6448.828	0.296	12904700.	32550.	0
59	58	1	6448.469	0.359	12869700.	35000.	0
60	102	2	6447.885	0.584	12832500.	37200.	0
61	66	1	6447.568	0.316	12795700.	36800.	0
62	43	1	6446.997	0.571	12756250.	39450.	0
63	118	2	6446.601	0.397	12720000.	36250.	0
64	54	1	6446.028	0.573	12684200.	35800.	0
65	3	4	6445.680	0.348	12653750.	30450.	0
66	42	4	6445.386	0.293	12623600.	30150.	0
67	66	2	6444.636	0.751	12577600.	46000.	0
68	64	2	6444.063	0.573	12541800.	35800.	0
69	111	3	6443.703	0.360	12500900.	40900.	0
70	39	2	6443.263	0.440	12462050.	38850.	0
71	16	4	6442.573	0.689	12414400.	47650.	0
72	128	1	6442.181	0.393	12382850.	31550.	128
73	147	3	6441.708	0.472	12336050.	46800.	0
74	25	2	6441.079	0.629	12303750.	32300.	0
75	79	2	6440.358	0.720	12271050.	32700.	0
76	96	3	6439.831	0.527	12226800.	44250.	0
77	143	2	6439.132	0.699	12184550.	42250.	0
78	69	2	6438.519	0.613	12149200.	35350.	0
79	3	3	6437.765	0.754	12103650.	45550.	0
80	78	1	6437.186	0.578	12063950.	39700.	0

COORDINATE NUMBER	TASK ELIMINATED MBPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	MBPA ELIMINAT MBPA
81	75	3	6436.459	0.727	12019500.	44450.	0
82	124	1	6435.883	0.576	11984350.	35150.	0
83	9	1	6435.160	0.723	11953300.	31050.	0
84	68	4	6434.392	0.768	11922500.	30800.	0
85	106	2	6433.899	0.493	11892450.	30050.	0
86	138	3	6433.356	0.542	11852800.	39650.	0
87	19	4	6432.661	0.695	11816350.	36450.	0
88	15	2	6431.546	1.116	11769550.	46800.	0
89	103	1	6430.511	1.034	11734100.	35450.	0
90	109	1	6430.187	0.324	11700200.	33900.	109
91	42	2	6429.587	0.600	11657650.	42550.	0
92	65	3	6427.962	1.625	11610300.	47350.	0
93	130	1	6426.589	1.373	11574600.	35700.	0
94	13	2	6425.837	0.752	11525550.	49050.	0
95	19	2	6424.440	1.397	11480750.	44800.	0
96	44	1	6423.669	0.771	11434300.	46450.	0
97	18	1	6422.829	0.840	11397300.	37000.	18
98	69	3	6421.338	1.492	11357550.	39750.	0
99	23	4	6420.697	0.640	11314600.	42950.	0
100	119	2	6419.618	1.079	11276800.	37800.	0
101	110	1	6418.756	0.862	11240400.	36400.	0
102	95	2	6418.024	0.732	11202200.	38200.	0
103	87	1	6417.114	0.911	11168550.	33650.	0
104	35	3	6415.760	1.354	11137600.	30950.	0
105	105	1	6414.230	1.530	11097000.	40600.	0
106	22	3	6413.116	1.114	11063650.	33350.	0
107	108	1	6411.423	1.693	11027700.	35950.	108
108	116	1	6410.353	1.070	10990450.	37250.	0
109	99	2	6409.051	1.302	10943400.	47050.	0
110	140	3	6407.643	1.408	10908800.	34600.	0
111	83	2	6406.509	1.134	10876600.	32200.	0
112	77	2	6405.057	1.452	10841400.	35200.	0
113	48	1	6403.827	1.230	10810800.	30600.	0
114	16	3	6402.221	1.606	10777900.	32900.	0
115	121	2	6400.031	2.189	10741850.	36050.	0
116	122	1	6398.281	1.750	10694650.	47200.	0
117	141	4	6396.198	2.083	10663200.	31450.	0
118	9	2	6394.553	1.645	10626150.	37050.	0
119	100	2	6393.809	0.744	10596100.	30050.	0
120	12	1	6391.169	2.640	10549400.	46700.	0

COORDINATE NUMBER	TASK ELIMINATED MOPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	MOPA ELIMINATED MOPA
121	10	4	6389.293	1.876	10506950.	42450.	0
122	17	3	6387.303	1.990	10465050.	41900.	0
123	77	1	6386.671	0.632	10428300.	36750.	77
124	127	3	6384.737	1.934	10387500.	40800.	0
125	49	3	6382.927	1.810	10350700.	36800.	0
126	113	2	6381.190	1.737	10311950.	38750.	0
127	136	4	6378.663	2.528	10271850.	40100.	0
128	50	1	6377.859	0.803	10225600.	46250.	0
129	145	1	6375.666	2.194	10182100.	43500.	0
130	145	4	6374.194	1.472	10138600.	43500.	0
131	140	4	6371.699	2.495	10093400.	45200.	0
132	103	2	6370.884	0.814	10059900.	33500.	0
133	76	1	6369.463	1.422	10016150.	43750.	0
134	55	1	6368.276	1.187	9982600.	33550.	55
135	115	2	6365.854	2.422	9936850.	45750.	0
136	137	2	6364.012	1.842	9899650.	37200.	0
137	19	1	6362.032	1.980	9853400.	46250.	0
138	8	2	6359.921	2.111	9818100.	35300.	0
139	121	1	6358.078	1.843	9781250.	36850.	0
140	137	1	6356.759	1.319	9732500.	48750.	137
141	86	2	6354.823	1.936	9698350.	34150.	0
142	7	2	6353.646	1.177	9662450.	35900.	0
143	99	4	6352.247	1.398	9620250.	42200.	0
144	136	2	6349.770	2.477	9574100.	46150.	0
145	4	3	6346.660	3.110	9528450.	45650.	0
146	31	1	6344.110	2.550	9496650.	31800.	31
147	141	1	6341.853	2.258	9465400.	31250.	0
148	81	2	6338.844	3.008	9422550.	42850.	0
149	126	2	6337.382	1.462	9387900.	34650.	0
150	46	1	6334.743	2.639	9347100.	40800.	0
151	62	3	6332.341	2.402	9314750.	32350.	0
152	16	1	6328.474	3.867	9265700.	49050.	0
153	136	1	6324.721	3.753	9234250.	31450.	0
154	114	2	6321.897	2.824	9186700.	47550.	0
155	2	1	6317.601	4.296	9153900.	32800.	0
156	29	2	6314.529	3.072	9120050.	33850.	29
157	123	3	6310.118	4.411	9082800.	37250.	0
158	17	4	6307.762	2.356	9034000.	48800.	0
159	117	3	6305.083	2.680	8999600.	34400.	0
160	20	1	6301.597	3.485	8952900.	46700.	0

COORDINATE NUMBER	TASK ELIMINATED MBPA	TASK	TECHNICAL VALUE EXCEEDED TOTAL	DELTA	COST TOTAL	DELTA	MBPA ELIMINATE MBPA
161	80	3	6298.783	2.814	8914200.	38700.	0
162	124	2	6296.498	2.285	8882450.	31750.	0
163	84	2	6294.404	2.094	8840700.	41750.	0
164	4	2	6291.179	3.225	8799450.	41250.	0
165	79	1	6287.971	3.207	8765950.	33500.	0
166	26	2	6284.754	3.217	8722000.	43950.	0
167	116	3	6280.782	3.972	8677000.	45000.	0
168	142	2	6277.736	3.046	8646400.	30600.	0
169	25	1	6274.637	3.099	8613900.	32500.	25
170	85	1	6273.249	1.388	8582750.	31150.	0
171	113	3	6270.392	2.856	8550550.	32200.	0
172	62	1	6265.189	5.203	8514800.	35750.	0
173	15	1	6260.561	4.627	8464900.	49900.	15
174	42	1	6256.353	4.208	8423150.	41750.	0
175	148	1	6250.641	5.712	8377550.	45600.	148
176	39	4	6245.691	4.951	8342050.	35500.	0
177	78	2	6239.892	5.799	8311200.	30850.	78
178	48	2	6237.644	2.248	8267450.	43750.	48
179	37	2	6232.318	5.326	8227200.	40250.	0
180	139	1	6228.462	3.856	8187	39550.	0
181	129	1	6223.157	5.305	81436	44000.	129
182	75	1	6220.065	3.092	8100200.	43450.	0
183	12	3	6211.625	8.439	8062850.	37350.	0
184	30	3	6205.923	5.703	8018100.	44750.	0
185	22	1	6201.956	3.967	7983200.	34900.	0
186	2	4	6195.985	5.971	7953100.	30100.	2
187	114	4	6191.973	4.011	7908800.	44300.	0
188	104	1	6188.117	3.856	7872950.	35850.	0
189	63	1	6184.557	3.561	7840700.	32250.	63
190	13	1	6179.818	4.738	7797550.	43150.	0
191	75	2	6171.365	8.454	7763500.	34050.	0
192	26	3	6166.172	5.193	7731050.	32450.	0
193	119	1	6158.381	7.791	7696000.	35050.	119
194	115	3	6153.081	5.299	7648150.	47850.	0
195	35	2	6146.100	6.981	7603350.	44800.	0
196	81	1	6140.674	5.426	7567400.	35950.	81
197	114	3	6136.116	4.558	7519850.	47550.	0
198	23	2	6130.810	5.306	7472600.	47250.	0
199	120	1	6127.478	3.332	7439700.	32900.	120
200	138	2	6125.336	2.141	7406650.	33050.	138

COORDINATE NUMBER	TASK ELIMINATED MOPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	MOPA ELIMINATED MOPA
201	107	1	6115.932	9.404	7369050.	37600.	107
202	96	2	6107.141	8.791	7322050.	47000.	0
203	71	2	6101.986	5.155	7280300.	41750.	0
204	92	3	6096.439	5.546	7246600.	33700.	0
205	127	1	6087.912	8.527	7199000.	47600.	0
206	62	2	6076.337	11.575	7154650.	44350.	62
207	36	1	6067.261	9.075	7118400.	36250.	36
208	149	1	6060.636	6.625	7085700.	32700.	149
209	86	1	6053.496	7.140	7040900.	44800.	86
210	141	2	6047.414	6.082	7003000.	37900.	0
211	127	4	6042.561	4.854	6970300.	32700.	0
212	134	1	6035.963	6.597	6936850.	33450.	0
213	97	2	6029.128	6.835	6906250.	30600.	0
214	83	1	6020.904	8.224	6875100.	31150.	83
215	34	2	6017.571	3.333	6834250.	40850.	34
216	94	4	6006.194	11.377	6801750.	32500.	0
217	37	4	5996.595	9.600	6770200.	31550.	0
218	144	1	5983.225	13.369	6738400.	31800.	144
219	95	4	5974.277	8.948	6695400.	43000.	0
220	79	4	5963.809	10.468	6659300.	36100.	0
221	122	2	5957.411	6.398	6612700.	46600.	0
222	7	1	5953.539	3.872	6568100.	44600.	0
223	115	1	5944.355	9.184	6537850.	30250.	0
224	111	2	5940.445	3.909	6507800.	30050.	0
225	69	1	5934.733	5.713	6469250.	38550.	69
226	127	2	5918.816	15.917	6420100.	49150.	127
227	98	1	5915.278	3.538	6389450.	30650.	0
228	65	2	5909.357	5.922	6353050.	36400.	0
229	56	3	5905.125	4.231	6321700.	31350.	56
230	104	2	5897.740	7.385	6291250.	30450.	104
231	13	3	5890.991	6.749	6261100.	30150.	13
232	95	3	5887.312	3.679	6227100.	34000.	0
233	110	2	5880.330	6.982	6192950.	34150.	110
234	72	1	5875.253	5.077	6160950.	32000.	72
235	10	1	5868.397	6.855	6124200.	36750.	0
236	54	4	5859.619	8.778	6075050.	49150.	0
237	9	3	5847.092	12.527	6029950.	45100.	0
238	73	1	5827.979	19.113	5982950.	47000.	0
239	130	4	5817.317	10.662	5934000.	48950.	0
240	87	2	5811.816	5.500	5902200.	31800.	87

COORDINATE NUMBER	TASK ELIMINATED MSPA	TASK	TECHNICAL VALUE TOTAL	TECHNICAL VALUE DELTA	COST TOTAL	COST DELTA	MSPA ELIMINAT MSPA
241	125	1	5803.671	8.145	5860850.	41350.	125
242	115	4	5785.807	17.863	5814550.	46300.	115
243	94	3	5778.645	7.163	5777850.	36700.	0
244	66	1	5772.869	5.776	5728900.	48950.	0
245	64	3	5765.761	7.109	5687050.	41850.	64
246	118	1	5756.987	8.774	5656200.	30850.	0
247	58	2	5752.068	4.919	5615700.	40500.	58
248	150	2	5742.046	10.022	5578050.	37650.	0
249	111	1	5735.382	6.663	5543350.	34700.	111
250	39	3	5717.835	17.547	5497600.	45750.	0
251	38	1	5711.113	6.722	5460350.	37250.	0
252	132	1	5697.982	13.131	5430350.	30000.	0
253	41	1	5691.635	6.347	5381900.	48450.	41
254	143	3	5674.657	16.978	5351350.	30550.	0
255	24	1	5669.337	5.320	5313050.	38300.	0
256	26	1	5657.950	11.387	5267100.	45950.	0
257	73	2	5650.983	6.966	5217300.	49800.	0
258	40	4	5646.485	4.498	5185650.	31650.	0
259	147	2	5640.068	6.417	5150700.	34950.	0
260	43	2	5630.626	9.442	5105100.	45600.	43
261	49	1	5620.986	9.639	5060900.	44200.	49
262	59	1	5609.639	11.347	5014350.	46550.	59
263	7	3	5588.229	21.410	4973650.	40700.	7
264	26	4	5576.367	11.862	4931500.	42150.	26
265	3	1	5569.822	6.545	4890000.	41500.	3
266	145	3	5546.476	23.345	4849150.	40850.	0
267	131	1	5533.911	12.565	4816250.	32900.	131
268	5	2	5527.881	6.031	4779850.	36400.	0
269	37	1	5513.730	14.150	4749200.	30650.	0
270	68	3	5494.050	19.680	4705750.	43450.	0
271	133	1	5486.011	8.038	4673700.	32050.	133
272	99	3	5459.240	26.771	4630150.	43550.	0
273	106	3	5451.529	7.711	4589150.	41000.	0
274	116	2	5427.097	24.432	4547100.	41450.	116
275	101	3	5407.651	19.446	4512800.	34900.	0
276	45	2	5390.233	17.418	4467600.	45200.	0
277	123	2	5374.986	15.247	4436050.	31550.	0
278	124	4	5365.465	9.521	4388800.	47250.	124
279	33	1	5343.274	22.190	4349550.	39250.	33
280	38	2	5330.907	13.267	4311850.	37700.	38

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COORDINATE NUMBER	TASK ELIMINATED MOPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	MOPA ELIMINATED MOPA
281	146	2	5306.420	23.587	4264150.	47700.	0
282	22	2	5285.092	21.328	4222550.	41600.	22
283	1	2	5263.868	21.224	4187150.	35400.	1
284	65	4	5243.186	20.682	4154550.	32600.	0
285	82	2	5236.443	6.743	4123550.	31000.	0
286	88	2	5222.897	13.546	4085400.	38150.	0
287	112	1	5204.906	17.991	4055400.	30000.	112
288	79	3	5180.402	24.505	4013750.	41650.	79
289	98	2	5159.384	21.018	3974550.	39200.	98
290	47	1	5148.910	10.474	3932500.	42050.	0
291	150	1	5135.293	13.617	3895700.	36800.	0
292	30	2	5114.731	20.563	3849600.	46100.	0
293	44	3	5095.691	19.039	3817800.	31800.	44
294	102	1	5076.647	19.044	3787000.	30800.	0
295	139	2	5052.030	24.617	3737800.	49200.	139
296	6	1	5032.589	19.440	3705400.	32400.	6
297	147	1	5008.898	23.691	3673400.	32000.	0
298	117	1	4984.232	24.666	3627150.	46250.	117
299	150	3	4961.021	23.211	3577400.	49750.	150
300	100	1	4933.549	27.473	3540100.	37300.	100
301	141	3	4917.460	16.089	3504550.	35550.	141
302	5	3	4907.409	10.051	3472300.	32250.	0
303	19	3	4882.023	25.386	3428650.	43650.	19
304	99	1	4849.969	32.054	3397650.	31000.	99
305	45	1	4826.929	23.040	3353600.	44050.	45
306	103	3	4816.748	10.181	3322600.	31000.	103
307	97	1	4791.618	25.130	3282400.	40200.	0
308	123	1	4750.614	41.003	3251750.	30650.	123
309	145	2	4728.587	22.027	3203150.	48600.	145
310	17	2	4715.498	13.090	3165400.	37750.	0
311	54	3	4690.177	25.321	3121550.	43850.	54
312	94	1	4671.328	18.849	3091500.	30050.	0
313	113	1	4659.426	11.902	3058450.	33050.	113
314	16	2	4617.222	42.204	3012200.	46250.	16
315	146	1	4584.094	33.127	2979100.	33100.	146
316	126	1	4556.679	27.416	2935700.	43400.	126
317	88	3	4530.118	26.561	2894350.	41350.	0
318	102	4	4493.641	36.476	2847300.	47050.	0
319	9	4	4454.473	39.168	2807900.	39400.	9
320	84	3	4434.839	19.634	2761100.	46800.	0

COORDINATE NUMBER	TASK ELIMINATED NBPA	TASK	EXPECTED TECHNICAL VALUE TOTAL	DELTA	COST TOTAL	DELTA	NBPA ELIMINATE NBPA
321	73	3	4393.690	41.149	2727000.	34100.	73
322	91	1	4359.418	34.272	2679100.	47900.	91
323	95	1	4341.021	18.396	2637750.	41350.	95
324	101	2	4326.806	14.215	2606950.	30800.	0
325	94	2	4307.172	19.634	2565050.	41900.	94
326	105	3	4280.681	26.491	2532950.	32100.	0
327	4	1	4258.284	22.398	2487050.	45900.	4
328	106	1	4232.582	25.702	2438400.	48650.	106
329	97	3	4212.948	19.633	2402400.	36000.	97
330	51	3	4167.874	45.074	2359850.	42550.	51
331	30	1	4139.315	28.559	2310300.	49550.	30
332	68	2	4098.695	40.620	2268950.	41350.	68
333	93	1	4071.565	27.130	2222300.	46650.	93
334	101	1	4031.585	39.980	2187000.	35300.	101
335	70	1	3971.294	60.291	2140450.	46550.	70
336	60	1	3942.203	29.091	2096450.	44000.	60
337	21	1	3921.006	21.196	2064500.	31950.	21
338	80	1	3891.387	29.619	2020050.	44450.	80
339	132	2	3869.791	21.596	1989550.	30500.	132
340	75	4	3803.827	65.964	1957450.	32100.	75
341	8	1	3776.338	27.490	1919350.	38100.	8
342	32	1	3727.184	49.154	1880300.	39050.	32
343	39	1	3698.624	28.560	1840850.	39450.	39
344	102	3	3674.626	23.998	1809450.	31400.	102
345	46	2	3637.971	36.655	1762450.	47000.	46
346	23	3	3600.736	37.235	1715450.	47000.	23
347	142	4	3565.037	35.699	1670800.	44650.	142
348	82	1	3531.323	33.715	1629100.	41700.	82
349	61	1	3473.789	57.534	1580100.	49000.	61
350	52	1	3410.200	63.589	1535900.	44200.	52
351	96	1	3367.358	42.842	1488300.	47600.	96
352	40	1	3322.375	44.983	1438800.	49500.	40
353	89	1	3293.819	28.556	1407950.	30850.	89
354	90	1	3248.836	44.983	1360100.	47850.	90
355	5	1	3211.145	37.691	1320200.	39900.	5
356	122	3	3171.160	39.985	1282050.	38150.	122
357	76	2	3117.846	53.314	1233550.	48500.	76
358	17	1	3068.760	49.086	1189800.	43750.	17
359	121	4	3030.360	38.400	1157250.	32350.	121
360	35	1	2975.820	54.540	1112750.	44500.	35

COORDINATE NUMBER	TASK ELIMINATED MBPA	TASK	TECHNICAL VALUE TOTAL	TECHNICAL VALUE DELTA	COST TOTAL	COST DELTA	MBPA ELIMINATED MBPA
360	35	1	2975.820	54.540	1112750.	44500.	35
361	92	2	2917.438	58.382	1065550.	47200.	92
362	140	1	2852.463	64.975	1017750.	47800.	140
363	66	3	2794.707	57.756	977200.	40550.	66
364	105	2	2692.820	101.887	935550.	41650.	105
365	147	4	2623.548	69.272	889100.	46450.	147
366	20	2	2511.835	111.713	849950.	39150.	20
367	14	1	2417.587	94.248	819850.	30100.	14
368	84	1	2368.501	49.086	789250.	30600.	84
369	118	3	2307.571	60.930	751750.	37500.	118
370	88	1	2252.236	55.335	718900.	32850.	88
371	85	2	2186.292	65.944	682450.	36450.	85
372	27	2	2131.287	55.005	652400.	30050.	27
373	67	1	2053.080	78.207	613400.	39000.	67
374	74	1	1943.422	109.658	566100.	47300.	74
375	50	2	1867.109	76.313	533550.	32550.	50
376	134	2	1775.482	91.627	495150.	38400.	134
377	47	2	1670.746	104.736	452300.	42850.	47
378	136	3	1579.119	91.627	415700.	36600.	136
379	24	3	1472.717	106.402	378250.	37450.	24
380	143	1	1379.635	93.082	346100.	32150.	143
381	53	1	1248.214	131.421	305950.	40150.	53
382	10	3	1133.957	114.257	273050.	32900.	10
383	65	1	952.537	181.420	223450.	49600.	65
384	42	3	835.641	116.896	191850.	31600.	42
385	130	3	669.046	166.595	151350.	40500.	130
386	114	1	517.106	151.940	114850.	36500.	114
387	37	3	377.464	139.642	83150.	31700.	37
388	12	2	171.832	205.632	36850.	46300.	12
389	71	4	-0.013	171.846	0.	36850.	71